DEFENCE R&D DÉFENSE

Technologies for workload and crewing reduction

Phase 1 Project report

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Defence R&D Canada

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Abstract

At the request of DGMDO, DRDC conducted a study of technologies for crewing reduction to catalogue known technologies, identify those that are applicable to the Canadian navy, and prepare proposals for a way ahead. Information received from contacts in Australia, The Netherlands, UK and USA, together with the results of two extensive literature reviews and world-wide-web searches was assembled into a matrix of technologies. The categories include whether the technology can be implemented at no cost to the ship, at minor cost, at major cost such as a refit, can be implemented in new ship builds, or will require further development to implement. Two workshops with the Working Group representatives and four focus groups with fleet operators were held to evaluate the applicability of these technologies to Canadian navy ships. Recommendations for the way ahead are that the Canadian navy should develop its own capability to evaluate workload and crewing reduction technologies and ship complements for existing and future ships. It is also recommended that DRDC should support that effort with short-term and longer-term activities.

Résumé

Sur demande de DGDOM, RDDC a conduit une étude des technologies pour la réduction des équipages des navires, pour cataloguer les technologies connues, pour identifier celles qui sont applicables à la marine canadienne, et pour préparer des propositions pour une voie en avant. L'information reçue des contacts en Australie, en Hollandes, au R-U et aux États-Unis, ainsi que les résultats de deux revues exhaustives de littérature et recherches du réseau mondial a été assemblée dans une matrice des technologies. Les catégories incluent si la technologie peut être mise en application à aucun coût au bateau, à un coût mineur, à un coût principal tel qu'une mise-à-jour , peuvent être mises en application dans de nouvelles constructions de bateaux, ou exigeront du développement ultérieur avant de mettre en application. Deux ateliers avec les membres du Groupe de Travail et quatre groupes de discussions avec les opérateurs de la flotte maritime ont été tenus pour évaluer l'applicabilité de ces technologies aux bateaux canadiens de la marine. Les recommandations pour la voie en avant sont que la marine canadienne devrait développer sa propre capacité pour évaluer les technologies pour la réduction des équipages et le charge de travail ainsi que pour évaluer les compléments pour des bateaux présents et futurs. Il est recommande également que RDDC devrait supporter cet effort avec des activités à court terme et à plus long terme .

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Executive summary

At the request of DGMDO, DRDC conducted a study of technologies for crewing reduction. The study was initiated in January 2001 with a completion date of June. The aim of the study was to catalogue known technologies, identify those that are applicable to the Canadian navy, and prepare proposals for a way ahead for reporting to the Maritime Research and Development Overview Group (MRDOG). Through TTCP HUM Technical Panel 9, information was solicited from contacts in the human factors research communities in Australia, The Netherlands, UK and USA. Briefings were received on the US Navy's Capital Investment for Labor, Smart-Ship, Integrated Command Environment and DD-21 projects. Two extensive literature reviews were completed and two searches were run on the world-wide-web. In addition information was solicited from the naval Points of Contact for the study, particularly on current complementing practice, the roles and tasks of personnel on current ships, and the costs of current crewing. In addition, lessons learned from crewing reduction projects were reviewed.

Some two hundred references to various workload and crewing reduction technologies were obtained from the international contacts and the literature and Internet surveys. This information was assembled into a matrix of technologies in terms of cost and the ship functions that it would support. Following the study terms of reference, the cost categories were based on whether the technology can be implemented at no cost to the ship, at minor cost, at major cost such as a refit, can be implemented in new ship builds, or will require further development to implement. The ship functions were based on the functional review of the Halifax and Iroquois classes and included Executive and Administration, Seamanship, Combat Systems Engineering, Marine Systems Engineering, Logistics, Damage Control and Emergency Response, Air Operations and Total Ship. Other categories that were added include Manpower and Personnel, Training, Complementing Practice, Operational and Support Concept, Procedures and Structure, and Supervision and Leadership. The matrix entries were then clustered into twenty-nine technologies, each cross referenced to the original material.

No information was obtained on the activities that determine the workload and crewing demands on existing ships, so it was not possible to evaluate the technologies that had been identified in terms of their potential to reduce workload on existing ships. Two workshops were held with representative from the Working Group and from PMO ALSC and PMO CADRE in which the twenty-nine technology clusters were briefly reviewed and rated for their applicability to Canadian navy ships. Four focus groups were held, two in Halifax and two in Victoria, in which operational personnel evaluated and discussed the various technologies. These groups made it clear that current, below strength, crewing levels are very onerous on crews, and that a significant proportion of routine maintenance tasks (up to 50%) were not being completed. The groups made it clear that any potential reduction in a ship's complement must be evaluated in terms of the effects on both primary, secondary and

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emergency crew roles and tasks. In addition there was a lack of confidence that the conditions necessary to implement some crewing reduction technologies would be maintained in the long term, particularly if the technologies were not directly linked to crew workload.

From the material reviewed it was concluded that the Canadian navy would be quite constrained in its application of crewing reduction technologies. Each technology must be reviewed in terms of its advantages and disadvantages, its effects on crew roles and tasks, training and career progression, supporting infrastructure, and policy and procedures. Recommendations for the way ahead are that the Canadian navy should develop its own capability to develop ship complements and to evaluate workload and crewing reduction technologies for existing and new ships. These efforts should be supported at the highest levels and include action to change the culture with respect to current crewing practice. It is recommended that DRDC should support the navy effort with short-term and longer term activities based on a review of the technologies that have been identified that require further development and that build on Canadian industrial capability.

Sommaire

Sur demande de DGDOM, RDDC a conduit une étude des technologies pour la réduction des équipages des navires. L'étude a été lancée en janvier 2001 avec une date d'accomplissement de juin 01. Le but de l'étude était de cataloguer des technologies connues, d'identifier celles qui étaient applicables à la marine canadienne, et de préparer des propositions pour une voie en avant pour faire rapport au Groupe Maritime de vue d'Ensemble de Recherches et de Développement (« MRDOG »). Par le Comité technique 9 du Groupe Facteurs Humains de « TTCP », l'information a été sollicitée des contacts dans les communautés de recherches de facteurs humains en Australie, Hollandes, du R-U et des Etats-Unis. Des présentations des Etats-Unis ont été reçus sur l'Investissement de Capital d'Equipement pour le travail, Smart-Ship, sur l'environnement de commande intégré et le projet DD-21. Deux revues exhaustives de la littérature ont été terminées et deux recherches détaillés ont été exécutées sur l'Internet . En outre l'information a été sollicitée des points navals de contact pour l'étude, en particulier sur la pratique complétante en vigueur, les rôles et les tâches du personnel sur les bateaux actuels, et les coûts des équipages actuels. De plus, des leçons apprises des projets de réduction des équipages et de leur charge de travail ont été passées en revue.

Environ deux cents références de diverses technologies de réduction des équipages et de charge de travail ont été obtenues à partir des contacts internationaux et des enquêtes de littérature et d'Internet. Cette information a été assemblée dans une matrice des technologies en termes de coût et fonctions de bateau qu'elle supporterait. Après le mandat d'étude, les catégories de coût ont été basées en fonction si la technologie peut être mise en application à aucun coût au bateau, à un coût mineur, à un coût principal tel qu'une mise-à-jour, ou si la technologie peut être mise en application dans de nouvelles constructions de bateau ou si elle peut exiger du développement ultérieur avant d'être mise en application. Les fonctions de bateau ont été basées sur l'examen fonctionnel des classes de Halifax et d'Iroquois et comprennait des fonctions tels direction et gestion, Seamanship, technicien de systèmes de combat, technicien de systèmes marin, logistique, commande de dommages et réponse de secours, exécutions d'air et bateau total. D'autres catégories qui ont été ajoutées incluent la main d'œuvre et le personnel, formation, complétant la pratique, le concept opérationnelle et de support, les procédures et la structure, et la surveillance et la conduite. Les entrées de matrice ont été alors groupées dans vingt-neuf technologies, chacune clairement référencée au matériel initial.

Aucune information n'a été obtenue sur les activités qui déterminent la charge de travail et des équipages exigés sur les bateaux existants, ainsi il n'était pas possible d'évaluer les technologies qui avaient été identifiées en termes de leur potentiel de réduire la charge de travail sur les bateaux existants. Deux ateliers ont été tenus avec le personnel du Groupe de Travail ainsi que les représentants des Bureaux de Projets « ALSC et « CADRE » auquel les batteries de vingt-neuf technologies ont été brièvement passées en revue et évaluées pour leur applicabilité aux bateaux canadiens

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de marine. Quatre groupes de discussions ont été tenus, deux à Halifax et deux dans Victoria, dans lequel le opérateurs de la flotte maritime a évalué et a discuté des diverses technologies. Ces groupes ont indiqué clairement que le niveau actuel des équipages, bien au-dessous de la force normale, est très onéreux sur les équipages, et qu'une proportion substantielle de tâches d'entretien courant n'étaient pas terminé (i.e. : jusqu'à 50%). N'importe quelle réduction potentielle d'un complément de bateau doit être évaluée en termes d'effets sur des tâches primaires, des rôles secondaires et de secours d'équipage . En outre il y avait un manque de confiance que les conditions nécessaires pour mettre en application certaines technologies de réduction des équipages seraient maintenu dans le long terme, à moins que l'on tienne compte simultanément de l'impact de ces technologies sur les tâches ou charges de travail.

En provenance du matériel passé en revue , il a été conclu que la marine canadienne serait très contrainte dans son application des technologies de réduction des équipages. Chaque technologie doit être passée en revue en termes de ses avantages et inconvénients, ses effets sur des rôles et des tâches d'équipage, sur la progression de formation et de carrière, sur l'infrastructure supportante, et sur la politique et les procédures. Les recommandations pour la voie en avant sont que la marine canadienne devrait développer sa propre capacité pour évaluer la charge de travail et les technologies pour la réduction des équipages et pour évaluer des compléments pour des bateaux présents et futurs. Ces efforts devraient être supportés aux niveaux les plus élevés et inclure l'action pour changer la culture en ce qui concerne la pratique de calculer les compléments en vigueur. On lui recommande que RDDC devrait supporter l'effort de marine avec des activités à court terme et à plus long terme basées sur un examen des technologies qui ont été identifiées qui exigent le développement ultérieur et qui établissent sur la capacité industrielle canadienne.

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Acknowledgements

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1. Introduction

1.1 Background

One of the highest through-life costs of operating naval ships is paying the crew who operate and maintain them. Using new technologies to reduce crew would appear to offer a way to reduce personnel costs while maintaining the ability to operate and fight the ship. Several navies have already conducted studies of modern materials and automation technologies as a means to reduce personnel costs while maintaining operational capability. Those studies have included career development and training issues as well as the more technical matters. In June 2000, under the aegis of TTCP HUM Technical Panel 9, Defence Research and Development Canada (DRDC) arranged for a briefing to NDHQ staff on the US Navy's DD-21 project to build a land-attack destroyer with a complement of 95 including the helicopter detachment[1], which represents a 79% reduction over current US Navy ships. Subsequently, DGMDO requested that a study be carried out to determine what can be done in the Canadian context (1). At the Maritime Research and Development Overview Group meeting held on 20 November 2000, it was agreed to begin the study with a relatively quick assessment of the situation and report back to the Group by about 1 June 2001. The aim of the first phase of the study was to:

- catalogue (list) the information already available from past and current studies on the crewing of warships,
- assess the applicability of this work to Canadian Naval vessels (including logistic support vessels) and
- recommend a way forward leading to the implementation of a reduced crewing strategy for Canadian naval ships.

Terms of reference (TOR) for the study were circulated and agreed (Annex A). Mr. David Beevis of DCIEM was appointed to manage the study supported by Dr. Andrew Vallerand, Directorate of Science and Technology for Human Performance (DSTHP) 3, and a contractor, Mr Mike Greenley of Options Inc. In order to gain a full cognisance of the issues that need to be considered and to identify related studies, both past and ongoing, representatives of the following organizations were appointed Points of Contact (POCs) for the study: DMMCP, DMRS, D Mar Strat, DMSS, MORT, DSTM, DNPP, DNPR, DSHRC, DMMPP, DREA.

[1] (The 'Key Performance Parameter Objective' was 95 with a 'threshold' of 150 assigned personnel)

1.2 Review of assertions/ premises

The study TOR include the premise that modern materials and automation technologies appear to offer a way to reduce personnel costs while maintaining the ability to operate and fight the ship. Personnel costs accumulate throughout the life of a system. Thus any study of the value of crewing reduction technologies must be based on through-life costs, not acquisition costs. There are several ways in which personnel costs can be reduced. The most obvious is to reduce the number of personnel; another is to reduce associated costs such as pay by changing the rank structure of personnel required, or by reducing training costs. An associated change would be to increase personnel productivity.

The reduction of personnel life-cycle costs through crew reductions is the basis of the US Navy's concept of Optimized Manning, which is summarized in Figure 1. This concept includes the premise that while large crews are flexible, small crews are less flexible and must be more responsive to mission demands.

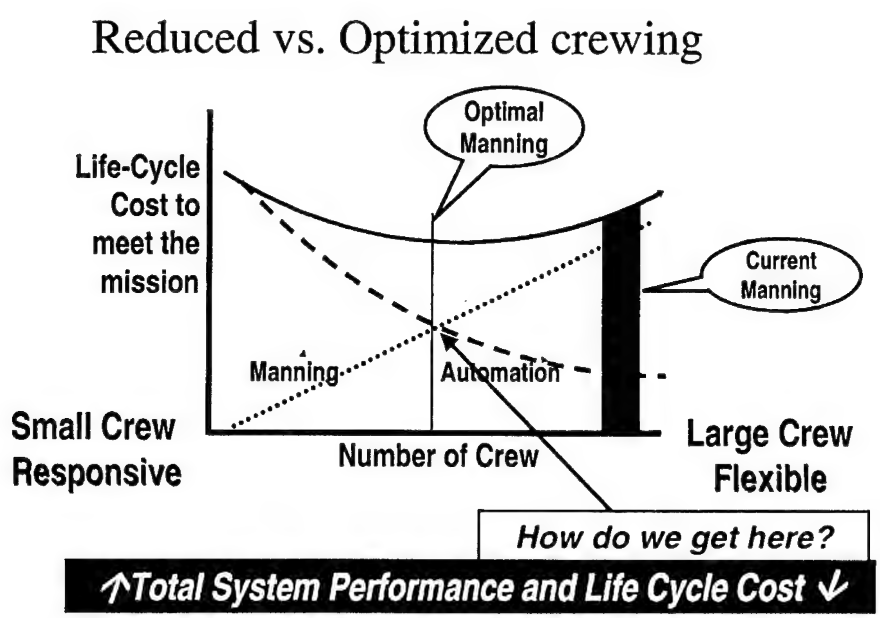

Figure 1. *US Navy's Optimized Manning Concept (reproduced by permission of Mr. Bob Bost, US NAVSEA)*

One of the study POCs, Dr. A. Jesion of DSHRC reviewed this concept. His comments are as follows:

> "I support the concept that Life Cycle Cost (LCC) goes up with the size of the crew manning a ship class. However, it may not be linear as the "Reduced vs. Optimized Crewing" figure shows. In fact, the function may have sizeable jumps and/or discontinuities when changing crewing policies. For example, when the crew size is modified to reflect additional constraints such as a more redundant watch-keeping policy or when the ship design is changed to accommodate additional equipment, sensors, weapons, etc. the LCC function will certainly not be linear. Similarly, in general LCC may be expected to go down as a result of increasing automation. However, as above, the function may have an unusual shape - vice the smooth parabolic decline shown in the figure. Therefore, it may be difficult to obtain the intersection point for optimal manning - in practice. If there are non-linearity's in manning and/or automation costs, but there are comparable in magnitude, then some form of optimization is still possible. If there are cost discontinuities, then the problem can still be solved, but some care must be exercised to find "good solutions" to the problem."

Another premise that was reviewed was related to the aim of identifying technologies that may be applicable to the immediate reduction of personnel numbers with no investment required in modification to ship systems or support infrastructure. This does not imply that solutions to crewing costs can be implemented without any cost. Any change, whether to equipment, systems, training or organization, incurs costs of some sort. The study TOR assumed that changes that involve no cost to modify ships, systems or equipment might be implemented through currently funded maintenance and training programs. However, other costs may be incurred to bring about the changes needed to reduce manning on CF naval ships. Effort will be required to implement reductions in crewing costs, and any reduction in ships complements will incur changes in personnel costs, in particular training and career management costs. One of the more difficult things to change will be the culture based on the current approach to crewing (2).

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2. Method

2.1 Approach to the Study

At the outset of the study, the TOR were expressed as a matrix, shown in Table 1. This provided three major work items for the study: review of potential solutions used by our allies; review of the applicability of those solutions to the Canadian Forces, and; development of recommendations for the way ahead.

Table 1: **Structure Of Information To Be Collected By The Study**

	Immediate application: no modification to ships	Technologies requiring minor changes to ships or infrastructure	Technologies requiring significant investment	Technologies applicable to new ship builds	Technologies requiring further R & d
Potential solutions *Solutions applied by allies* *Solutions applicable to CF* *Recommendations for way ahead*					

The first phase of the study was initiated by a review of information already available through TTCP HUM Technical Panel -9 on Human Factors Integration for Naval Systems. That information was supplemented by a literature review, a search for information available on the world-wide-web, discussions with Canadian subject matter experts (SMEs) and discussions with experts in The Netherlands, UK and USA.

In the second phase of the study, two workshops were held to review the technologies that have been used or proposed by our allies. In the first workshop, the POCs appointed to the study used the NDHQ Decision Support Laboratory to independently rate each technology and provide comments on them. A second workshop was held to obtain the ratings of experts from the Afloat Logistic and Sealift Capability (ALSC) and Command and Control and Area Air Defence Replacement (CADRE) Project

Management Offices (PMOs). Two focus groups were also held with fleet Subject Matter Experts (SMEs) from both MARLANT and MARPAC, to review the technologies.

In the third phase the results of the workshop were reviewed and recommendations developed for Phase II of this study. A draft report was circulated for comment from the POCs and ALSC and CADRE projects, and clarifications and amplifying material added where necessary.

2.2 Information received through TTCP HUM TP-9

Since 1996, TTCP HUM Technical Panel 9 has provided a medium for collaborative research and development with Australia, the UK and USA on Human Factors Integration in Naval Systems. Key Collaborative Area 3 of TP-9 is devoted to 'Tools for optimizing naval platform manning and manpower requirements.' Material provided though TTCP TP-9 since 1996 was reviewed for relevance to the study. In addition, information was requested through TP-9 members on progress in the US and Royal navies. The Chair of TP-9 and US National Leader, Mr. Bill Nugent made available a listing of US Technologies for Optimized Manning (TOM) material that he compiled. The UK National Leader, Dr. Colin Corbridge provided a list of UK TOM material that he had compiled for the purposes of a joint US/UK workshop. Other information was requested from UK contacts, but despite agreement to provide material, none has been received at the time of writing. Australia had previously provided information on its shipboard manning model, and the Fleet Onboard Command Update System (FOCUS) computer program for reporting and monitoring Damage Control (DC) incidents and the subsequent follow-up action.

2.3 Literature review

A literature search was conducted using the US National Technical Information System (NTIS) database. Search terms included: "manning OR manpower OR crew size OR operation? analysis? OR personnel requirement? AND: ships OR shipboard OR naval OR vessel? ? OR smart ship?" The search identified 1197 possible titles. Many titles were related to manpower, personnel or training issues, especially retention. Most of these references were excluded from the study because they were not considered to contribute to reducing crewing, although they are important issues in implementing crewing reduction. The list was reduced to 120 references by inspection. Sixty-eight of those reports were then selected for review on the basis of the abstracts. Only two or three of these reports were from non-US agencies. The reports were distributed among the three authors for review. A limited number were sent to specialists for review. If the material in the report was judged relevant to the study the reference and an abstract were prepared.

In addition, material that had been collected during Subject Matter Expert (SME) interviews to identify requirements for the ALSC project was also reviewed.

2.4 Internet review

Two searches were conducted on the Internet using terms such as manning, ship manning, manning reduction, crewing, crew reduction and ship, and ship automation. This Internet search included the US navy sites for information on Smart Ship and the SC-21projects and the Manning Affordability site maintained by the US Office of Naval Research (http://www.manningaffordability.com/S&tweb/Index_main.htm).

2.5 Visits to allied experts

Discussions were held with a contact in The Netherlands TNO Human Factors Research Institute who had previously exchanged information on approaches to crewing reduction. It was agreed that there would be value in holding a three-day workshop on crewing reduction, but the timing of the proposed event was not suitable to the Royal Netherlands Navy (RnlN) project officer and the workshop was cancelled.

Proposals for visits to UK agencies were cancelled due to lack of response to requests for information from DERA project officers.

The US member of TTCP HUM TP-9, Mr. Bob Bost, organised visits to and demonstrations and briefings by three current US Navy programmes: the Capital Investment for Labour project which is exploring changes to current work practices, materials, finishes, etc.; the Smart Ship project which is exploring retrofits to existing ships and; the Integrated Command Environment (ICE) Ops Room system being developed at the US Navy Surface Warfare Center, Dahlgren, Virginia.

2.6 DND POC review

The Points of Contact for this study (Section 1.1) were asked to provide material on relevant Canadian projects. Information on the 1999 evaluation of a two-watch system for marine systems engineering departments was received (3). No other information was received. In addition to commenting on the US Navy's Optimized Crewing concept (above) Dr. A. Jesion of DSHRC commented on five US reports on the economics or cost-analyses of different approaches to crewing. Dr. R. Morchat of DREA Dockyard Labs reviewed and commented on several reports on improved finishes and paints.

Ten of the Points of Contact also attended a workshop on the 25 April at which they rated the applicability of the 29 technologies to Canadian naval ships. The permanent Decision Support System (DSS) lab in NDHQ at 101 Col By was used for the workshop. Each participant sat at a computer workstation, and was logged on to a unique instance of the DSS. The DSS was configured for three activities:

1. A rating activity, which allowed participants to rate the applicability of each of the 29 clusters of crewing reduction technologies to Canadian naval operations.

2. A grouping activity, which allowed the participants to indicate to which ship class(es) a proposed technology applied.

3. A list creation activity, which allowed the participants to suggest new technologies, not yet identified by the core project team.

In order to rate applicability the participants were provided with an on-line groupware tool with the questionnaire installed. The questionnaire listed a number of technologies and asked the participants to rate applicability on a seven point scale. For the purposes of the workshop applicability was rated on a seven-point scale from a rating of:

(1) = Not at All Applicable, to a score of (7) = Very Applicable.

Participants were able to make comments during all three activities. The DSS was configured such that all input was anonymous, but all participants could view all inputs to the system and comment on them.

Eight experts from the ALSC and CADRE project offices attended a second workshop to review the technology clusters on the 24 May. The workshop involved open discussion of the merits and demerits of each technology cluster, and the participants rated the applicability of the technologies to their project (ALSC or CADRE) using individual rating sheets and the same scale of 1 to 7.

The results from the workshops were compiled into a report (4) that has been installed on the Crewing Reductions Technology special project area (password-controlled) of the Human Systems Integration (HSI) web-site maintained by DRDC on the Defence Wide Area Network (DWAN) (http://admst-002.d-ndhq.dnd.ca/hsi/special) and Internet at (http://www.drdc-rddc.dnd.ca/hsi/special/)

2.7 Naval focus groups

Mr. Greenley of Options Inc. conducted focus groups in Halifax and Victoria during the week of 16 April 2001. East Coast groups included personnel from HMCS Ville de Quebec, HMCS Halifax, and East Coast Sea Training staff on board HMCS Ville de Quebec in Halifax harbour. West Coast groups included personnel onboard HMCS Ottawa and West Coast Sea Training staff in Victoria. In total 45 personnel were involved in the focus groups, from most ship departments, covering all ranks from Leading Seaman to Lieutenant Commander. During each focus group M. Greenley reviewed the list of technologies that had been identified in the literature with the participants. Discussions around each technology area focused on the applicability to Canadian naval operations, followed by the elicitation of any additional suggestions the participants had. All inputs were summarized into a report (5) that has been

installed on the Crewing Reductions Technology special projects area of the HSI web-site maintained by DRDC.

2.8 Information on the CF complementing process

Several agencies in NDHQ were approached for information on the process followed in DND to establish the complement for the various ship classes. Interviews with personnel from DMSS, DNPR and acquisition projects were held in person, by phone, during focus groups and during the workshops. It was unanimous that there is currently no formal complementing process in Canada. Information from several sources indicated that ship complements are determined through two streams:

- On new ships, the contracting community, through interactions with the project office, determines the complement of the ship they design and deliver,

- Personnel in DNPR manage the deployed complement on existing ships. Ship staff are able to raise reports that identify the need for complement adjustments to DNPR staff who then proceed to try to meet the deficiency.

2.9 Information on ship personnel cost centres

A number of attempts were made to identify the personnel related to cost centres on Canadian navy ships. The CPF /TRUMP Establishment Review report was studied, as was the DND Cost Manual, but neither document provided the necessary information. Requests for information were distributed and the DWAN was searched extensively for information on personnel costs. However, insufficient data were located to be able to determine how many personnel of each rank and trade level were currently posted on each ship class to be able to determine the relative cost drivers. Obviously this information exists within the naval community in some form, but it was not identified or provided during the study and must be located for use in any future phase of this work.

2.10 Current crewing situation

The authors received little information on current practice. They were aware of statistics from a study of ship's husbandry carried out by DMSS some years ago (389 hours effort per day for cleaning stations) and that less than 50% of preventative maintenance routines are completed (6), but no material was received in response to requests for information on current crew structure, costs, and work assignments. The authors requested information on specific complement levels in each ship through a naval liaison officer, but nothing had been received at the time of writing.

The focus group meetings provided some information on the current workload and crewing situation. Currently a number of ships lack a full complement. This in turn results in increased workload for those who are on board. Examples where complements were under strength included:

- One ship that routinely operates with 22 of the required 30 officers.
- Another ship that currently had 50 empty billets as a result of having their crew assigned to other ships to allow them to go to sea.

In general it was reported that there are simply not enough naval personnel to fill the required positions on current vessels. As a result, vessels are already operating with reduced crew sizes and certainly could not operate with less.

Interviews with fleet personnel indicated that when a complement is under-strength:

- The workload for those on board increases.
- Maintenance tasks do not get completed. One ship produced graphs indicating that on average 50% of the required maintenance tasks at the six-month frequency did not get completed. Because these bi-annual tasks are generally very important, smaller maintenance tasks were even less likely to get completed.
- Senior staff has to complete tasks historically conducted by junior personnel (according to reports the Maritime Other Ranks Production Study (MORPS) of 1978 reached the same conclusion).
- Personnel get assigned off of their ship to help fill another ships' complement so that it can go to sea.
- When personnel return from helping another ship while at sea they are often assigned to another ship again, return to help with their own ships continued maintenance, or are sent off from training. This results in little time off or time away from ship work.

As a result of these effects it was reported that many personnel choose to leave the military as they either (a) do not get to do what they signed up for – go to sea, and/ or (b) they do not get sufficient time to spend with their families, and/or (c) they are overworked and stressed[2]. Again, these conclusions echo reports of the 1978 MORPS study findings. Of course poor retention in turn adds to the problem of reduced personnel numbers.

2.11 US Navy technologies

The USN Capital Investment for Labour project is exploring changes to current work practices, materials, finishes, equipment, and furnishings, see (http://maintenance.navsea.navy.mil/domino/sea04m2/04m2cil.nsf/ciMain).

[2] (While these two reasons appear contradictory, they are supported by observations in other navies. Younger personnel are eager to spend time at sea; older personnel are more concerned about spending time with their families).

The Smart Ship project (http://www.dt.navy.mil/smartship) is exploring a range of retrofits to existing ships, from changes to the watch system and installation of wireless communications around the ship to the retrofitting new integrated bridge systems and machinery control systems (summarized at Annex B). The complete briefing on Smart Ship is included in the Crewing Reduction Technologies section of the DRDC Human Systems Integration web-site. The Smart Ship project office also provided copies of the papers presented at the NAVSEA 'Intelligent Ships Symposium IV' held in Philadelphia at the beginning of April.

The Integrated Command Environment (ICE) facility being developed at the US Navy Surface Warfare Center, Dahlgren, Virginia, represents a long-term development to reduce the number of crew and improve the performance of the Operations Room system, see (http://www.manningaffordability.com/S&tweb/Index_main.htm). Information from these projects was assigned to the categories of minor changes, significant investment, new ship builds, and technologies requiring further development.

The US also ran a series of joint workshops with the UK that reviewed Technologies for Optimized Manning. Both UK and US provided information on the workshops. One workshop concluded that the technologies that have most potential to reduce manning are: tools to build and maintain Situational Awareness in operators; teleoperator technologies to support remote specialists and; central monitoring systems.

2.12 Catalogue of potential technologies

The information obtained from the literature review, Internet search and TTCP sources was reviewed for relevance and each item was entered into the matrix developed from the study TOR (Table 1). Each referenced technology was categorized according to whether it could be applied with no, little, or major modification to the ship, or was applicable in new ship builds or required further research, and according to which of the functions identified in the CPF/TRUMP Establishment Review it would support. This resulted in almost two hundred separate references in a matrix of 135 cells (Annex C). These references and abstracts were documented in a separate report. In response to enquiries from industry, a version of this catalogue was prepared which contained only material which the source agencies approved for distribution to non-government agencies.

2.13 Technologies applicable immediately with no modification to ships

This category comprises changes that can be implemented without modifying the ships. Thus it is restricted to topics such as policy, procedures, practice, and training. The studies to reduce 'cumbersome work practices' that are part of US NAVSEA's Capital Investment for Labor project are relevant to this category. It includes:

- Moving administrative and maintenance tasks from ship to shore
- Contracting out support functions
- Consolidating and simplifying instructions and information
- Changing the rank structure, combining trades, or assigning lower ranks to tasks
- Changing the roles and missions of ships
- Sequencing tasks, readiness checks, etc.
- Changing the ship to shore ratio
- Changing watch systems
- Improving training and reducing training time
- Improving productivity through leadership.

2.14 Technologies applicable immediately with minor changes to ship systems or infrastructure

This category comprises changes that can be made to ships at relatively low cost. The developments being made by the US Navy's Capital Investment for Labor project are relevant to this category. It includes:

- Low maintenance materials and finishes
- Wireless communications on board
- Smart ID cards
- Electronic manuals
- Automated teller machines.

2.15 Technologies applicable to existing ships through significant investment

This category comprises changes that can be made to ships through significant investment. It includes most of the technologies being applied in the US Navy's Smart Ship project. Implementation of changes at this level requires a thorough review of existing crew functions and tasks with the aim of automation, consolidation,

simplification or elimination (7). Such changes can be explored through modelling and simulation of crew tasks. The category includes:

- Analysis of functions and tasks
- Modelling and simulation of crew tasks
- Changing equipment location to permit operators to perform multiple tasks
- Installing commercial Integrated Bridge Systems
- Using voice recognition to replace crew members
- Installing electro-optical systems for lookout and surveillance
- Commercial mooring lines and equipment
- Improved Replenishment at Sea (RAS) and Underway Replenishment (UNREP) equipment
- Using canister and 'fire and forget' weapons
- Improved Ops Room systems such as the US SPAWAR Multi-modal Watchstation
- Centralized machinery monitoring and control systems
- Improved sensing, machinery health-monitoring and condition-based maintenance systems
- Improved food services
- Improved husbandry
- Improved waste-treatment systems
- Telemedicine systems
- Centralized damage control information systems
- Fibre-optic Local Area Networks
- Improved on-board training systems

2.16 Technologies applicable to ships of new construction

This category comprises technologies that can be implemented in new ships. In recent years, design studies that have reduced crewing as a goal have used a top-down analysis of roles, functions, and tasks. The functions and tasks can then be reviewed with a view to automation, consolidation, simplification or elimination (7). This process was followed by the Royal Netherlands Navy in their amphibious support ship project of the early 1990s, and for subsequent projects, and was adopted by the US Navy's DD-21 project, and by the Royal Navy for the Type 45 project. The category includes:

- Advanced complementing practice
- Minimum manned bridge designs
- Minimum manned RAS systems
- Minimum manned UNREP systems
- Corrosion minimizing designs, material and coatings
- Integrated Ops Room systems such as NAVSEA's ICE
- Redundant ships systems
- Highly reliable systems
- Electric propulsion
- Integrated, intelligent, machinery monitoring, diagnosis and control
- Maintenance management systems
- Minimum manned cargo and stores handling design
- Revised policy and design for reduced damage control
- Integrated platform control
- Automatic fire detection and suppression systems
- User-friendly operator-machine interfaces
- Advanced ship design processes such as the NATO virtual ship design cycle
- Embedded advanced training technology.

2.17 Technologies requiring further development

This category includes some 'high tech' developments that have the potential to reduce crewing levels in the future, but which require further development. It includes:

- Artificial intelligence and advanced decision aids for combat and machinery systems
- Improved crew models and simulations
- Identification of total operating costs
- Tele-presence
- Robotics
- Advanced power systems (electrical, fuel cells)
- Wear-resistant materials
- Advanced lubrication systems
- Micro-mechanical systems
- Enhanced mission electronics
- Automated food services
- Damage control automation
- Advanced computer operations support systems
- Tailored training
- Optimized detailing
- Practices for getting crew performance monitoring and improvement.

2.18 Combination of technology solutions

These various technological solutions were then combined into twenty-nine clusters of technologies (Table 2). This list, the matrix, and the references and abstracts were combined into a file that is accessible in the Special Projects section of the DRDC HSI web-site. A summary of the list, matrix, and technologies is attached as Annex C. The twenty-nine clusters of potential solutions were then rated by the study Points of Contact for their applicability to Canadian naval ships.

Table 2: Clusters Of Crewing Reduction Technologies

1.	Complementing Capability
2.	Human Systems Integration Process
3.	Role and Task-based Modelling
4.	Modifications to Crew Structure
5.	Virtual Presents
6.	Enhanced Training Systems
7.	'Move Administrative Tasks Ashore
8.	Enhanced Information Technology
9.	Move Maintenance Ashore
10.	Enhanced Maintenance Planning
11.	Low Maintenance Finishes and Materials
12.	Improved Husbandry
13.	Enhanced Ergonomics In Layout
14.	Video Surveillance
15.	Enhanced Operator-Machine Interfaces
16.	Decision Support Systems
17.	Distributed Monitoring and Control Systems
18.	Low-Labour RAS
19.	Low-Labour Propulsion Systems
20.	More Reliable Systems
21.	Enhanced Materials handling
22.	Streamlined Food Services
23.	Anchoring and Line Handling
24.	Damage Control Systems
25.	Unmanned Aerial Vehicles
26.	Alteration to Related Policy
27.	Focused Mission Profiles
28.	Streamlined Procedures
29.	Manage Personnel Productivity

2.19 Focus group reviews of applicability of technology clusters to Canadian naval ships

Focus groups avoid canvassing individual opinions and, if properly conducted, represent a balance or consensus of views. Although it would have been preferred to run several more groups than time or resources permitted, the consistency of the observations across the four groups in two commands suggests that the observations that were documented are reliable.

The focus group participants did not offer many novel strategies or technologies for workload or personnel reduction. Several technologies identified through the review of literature and contacts with other countries are already in use by Canada, or had

been used by Canada in the past. In these cases the participants provided important advice regarding how to best implement such an idea, through statements such as "...that works, but...".

In general, the solutions or technologies discussed were identified as candidates to reduce workload provided that a series of secondary factors were properly considered. These secondary factors included the need to consider the impact of a technology on (i) the full range of ship functions, (ii) on the secondary tasks performed by personnel who may be removed from the ship as a result of full scale implementation, and (iii) that senior management's commitment to fund the infrastructure required to allow the ship to realize the benefits of a workload or crew reduction technology throughout the life cycle of a ship.

The single most consistent thread of discussion across all meetings was the need to consider the impact of any technology, suggestion, or solution on the full range of ship functions and on all the secondary tasks that are performed by personnel on the ship. Such an analysis requires project teams to fully understand the range of scenarios that the ship will be tasked to complete, followed by a systematic analysis of who will perform the primary, secondary and emergency functions aboard the ship across this full range of scenarios. This type of analysis is required both during the acquisition/design of a vessel, but also throughout the ship's deployed life cycle to ensure that the complement is correct and sufficient. Participants indicated that this systematic consideration of ship personnel requirements and regular studies of ship workload, should be completed by "the centre" and not be pushed down as additional duties for ship personnel to complete, as is currently the case in many studies.

Another consistent set of inputs was a general lack of confidence that senior management will maintain the policy and infrastructure required to realize the benefits of new technology. Fleet personnel noted that modifications to the concept of operations, ship missions, support structures, crewing concepts etc., established to reduce overall through life costs within a balanced crew workload, can be eliminated by future policy makers without any consideration for ship complement, workload, or quality of life. A prime example was the CPF Fleet Maintenance Group (FMG), which was established to provide shore-based maintenance as a key enabler for workload and complement reduction (see Table 2, Item 9). Surprisingly, it was cut, post deployment, resulting in an unachievable maintenance workload for the ships' crews. Another example was the surfaces and finishes that should lead to reduced maintenance, but for which there is insufficient funding for their proper application. Fleet personnel emphasized that there should be some form of central complementing analysis capability that could evaluate the impact of potential changes, such as the closure of FMG, on crew sizes and workload. The same analysis capability should be used to study the impact of mission or task changes.

Areas that were consistently identified as candidates to potentially reduce personnel numbers on future ships included maintenance/machinery, administration/bureaucracy, and the Ops Room area – as long as any changes in these functions were considered in

terms of their impact on whole ship operations. In view of the emphasis placed on workload problems by operational personnel, it was decided that the title and aims of the project should be revised to include 'technologies for workload or crewing reduction.'

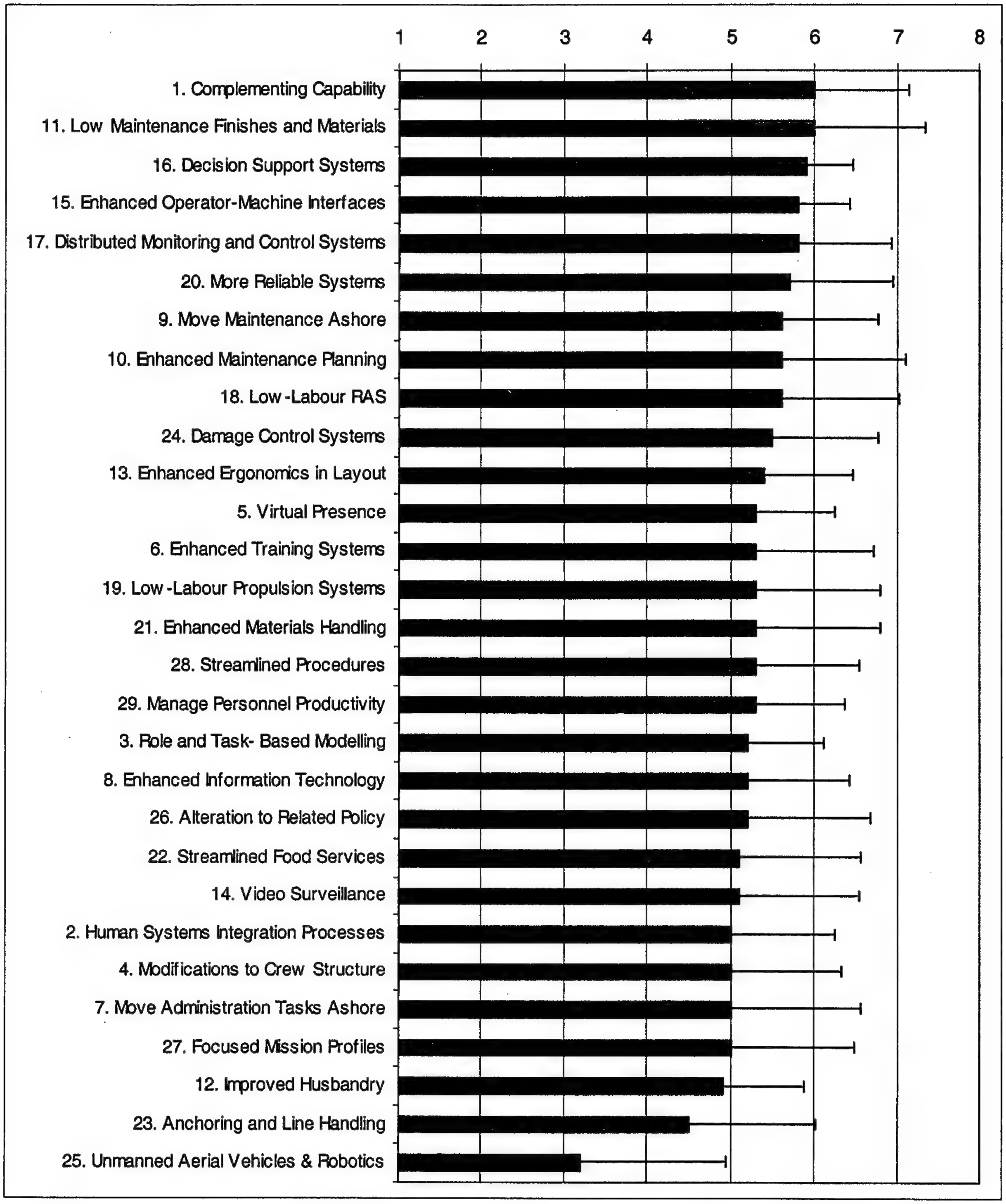
2.20 POC ratings of applicability of technologies to Canadian naval ships

The ratings obtained in the two technology review workshops were averaged and the results used to rank the 29 technology clusters. As shown in Figure 2, the average ratings for applicability of almost all of the technology clusters was 4 or greater, indicating that they are all applicable to some extent. The two exceptions were the applicability of robotics and Unmanned Air Vehicles (UAVs) to current ships and the applicability of focussed mission profiles to future ships.

An additional observation from Figure 2 is that, while both groups rated the majority of technologies as applicable, the future ship group rated the majority of the technologies as applicable and rated them at higher values than the group that rated applicability to current ships.

During the first workshop an additional rating activity was completed to indicate the applicability of the technology clusters to the different classes of Canadian naval ships. This exercise showed larger differences on both the overall spread of ratings and on the pattern of ratings across the 29 technology clusters. TRUMP, MCDV and AOR classes received the lowest ratings overall due to expectations that there is comparatively little opportunity for modifying those ships. The details of those ratings are available in the workshop report (4).

The workshop report also contains details of participant input on additional issues and suggestions related to technology implementation. Those comments should be read with those from the focus group report (3) for comments on advantages and disadvantages of the various technologies and for other details that would enhance further studies.



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7
8
1. Complementing Capability
11. Low Maintenance Finishes and Materials
16. Decision Support Systems
15. Enhanced Operator-Machine Interfaces
17. Distributed Monitoring and Control Systems
20. More Reliable Systems
9. Move Maintenance Ashore
10. Enhanced Maintenance Planning
18. Low-Labour RAS
24. Damage Control Systems
13. Enhanced Ergonomics in Layout
5. Virtual Presence
6. Enhanced Training Systems
19. Low-Labour Propulsion Systems
21. Enhanced Materials Handling
28. Streamlined Procedures
29. Manage Personnel Productivity
3. Role and Task- Based Modelling
8. Enhanced Information Technology
26. Alteration to Related Policy
22. Streamlined Food Services
14. Video Surveillance
2. Human Systems Integration Processes
4. Modifications to Crew Structure
7. Move Administration Tasks Ashore
27. Focused Mission Profiles
12. Improved Husbandry
23. Anchoring and Line Handling
25. Unmanned Aerial Vehicles & Robotics

Figure 2a. *Applicability Ratings for Current Ships Sorted by Average Rating*

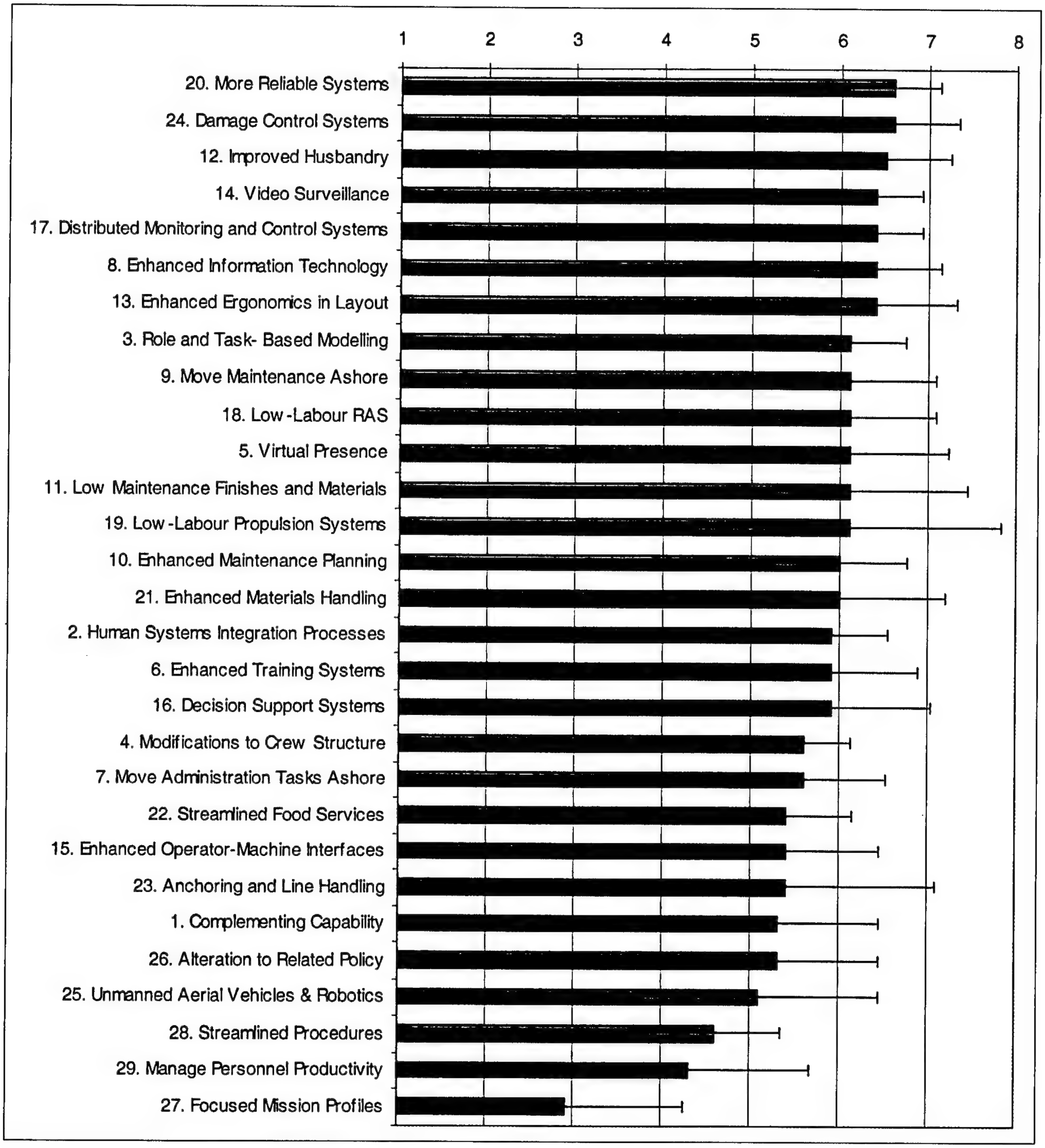

Figure 2b. Average Ratings of Applicability to Future Ships

2.21 Review of lessons learned

In addition to compiling the matrix of technologies, reports were reviewed for lessons learned. One clear pattern of findings is that the evolutions that drive requirements for crew are Damage Control, Replenishment at Sea (RAS), and maintenance (8, 9). In addition, ship condition or readiness state drives workload: in US Navy ships, in condition III more than 30% goes to operational manning, 25% to own ship support, and 17% to maintenance; in Condition I, more than 50% goes to damage control (10).

The US Navy Manning Affordability project completed three studies of lessons learned from manning reduction studies (13, 14). The findings from one are summarized at Annex D. One of the most important is that no major savings were achieved by implementing technology without a human factors engineering, or human systems integration programme. The study found examples of successful reduction "only when the goal was to improve performance by cutting unnecessary team members." They did "not find examples where technology insertion was effective in reducing staff size" without the goal of reducing crewing levels. The case studies conclude that implementations must have support from the top and require changes to the current naval culture.

Another case study (15) concluded that, to be successful, crewing reduction efforts have to:

- anticipate future missions,
- have a clearly stated goal of crew reduction,
- find leverage points where changes with high payoffs can be implemented,
- iterate through trial and error, and accept the possibility of error in early stages,
- address training, which is a key issue in small-crew ships,
- work out the implications that reduced crewing has for multiple operational roles,
- manage the implementation of changes.

Other reports showed that several attempts to reduce manning on naval ships have been compromised because assumptions that were made early in the project were not

maintained once the class was in service. The Royal Navy's Type 23 was intended to be a towed array ship but its role was subsequently expanded to that of a general-purpose frigate (11). In both the Type 23 project and the US Navy's FFG-7 project it was assumed that a shore support unit would carry out maintenance (11, 12, 13). In both cases that policy was subsequently abrogated, with a resultant increase in maintenance duties for ships' crews. Regrettably, the same is reported to have happened with the CPF.

The RN Type 23 experience illustrates the clear link between policy and ship missions. Other examples of the effects of policy include: the policy that makes a Captain responsible for the security of the ship and the resulting reluctance to have contracted personnel complete duty watches; policies that permit a ship to be tasked by the Department of Foreign Affairs and International Trade (DFAIT) in foreign ports which unpredictably interferes with other ship duties, etc. Thus, even with a complementing process that includes a human systems integration process on future ship acquisition projects that may result in revolutionary personnel changes, significant leadership and a policy of crew/workload level management will be required to overcome these significant barriers.

Possibly the most important lesson is that attempts to reduce crewing levels will be successful only if the current culture is changed. At the most general level the need for a changed culture can be expressed as the need to overcome the uncertainty associated with changing the practices that have been developed to allow a ship to operate in harms way. The culture based on current practices may be the biggest hindrance to crewing reductions or the effective employment of crew. Canadian examples that were identified during this project include:

- the attitude that personnel should not use new technology because "we always do it the old way";
- officers who feel "scrubbing high maintenance deck surfaces is good for morale";
- senior personnel who feel that "cleanliness requires a daily routine regardless of the actual state of the ship";
- attitudes that good food requires a high on-board labour content, or that a senior officer must have a steward as it has "always been that way".

3. Discussion

3.1 Scope of the material reviewed

Because of contacts established through TTCP HUM TP-9, it was comparatively easy to obtain information on activities related to crewing reduction in Australia, the UK and USA. In contrast, little information was obtained on Canadian developments that might be relevant to the project. The authors are sure that there have been several studies that are relevant to the review of crewing reduction technologies, but no information was received in response to solicitations, other than the study report on the trial of the two-watch system for Maritime Systems Engineering Personnel (MSEPs).

The material reviewed was restricted to technologies that had been used or recommended for their potential to reduce workload or crewing. These technologies include developments or changes in policy and procedures as well as software and hardware materials, components and sub-systems, and technologies for improving the estimation, costing, and application of new technologies. Because of the limited resources available for the study, material on recruitment, selection, career management, retention and the quality of life was excluded on the grounds that such technologies are necessary for implementing reduced crewing, but do not contribute to achieving reductions in complements.

The authors adhered to the TOR focus on identifying technologies that might contribute to crewing reductions. They did not investigate the operational implications of reduced complements such as the decrease in flexibility mentioned in Section 1.2. Such implications are clearly important but require thorough examination of, and possible changes to navy policy. For example one reviewer of this report noted "In the current fleet, ships are required to provide 20 personnel for boarding parties. These are generally split into 2 teams of ten. In the case of HMCS CHARLOTTETOWN and WINNIPEG in their recent Persian Gulf deployments, two twenty man teams were required. In a ship with a notional complement of 100 to 150, these numbers would be unattainable without external augmentation. In fact, the 40 personnel required could not be supplied in the above cases from within ships companies of approx. 240, requiring augmentation of the ships companies by 20 person US Coast Guard law enforcement teams."

3.2 Review of achievements in crewing reduction to date

From the material reviewed in this study it seems clear that the need to reduce crewing levels on naval ships has been recognised since the early 1970s when the NATO Defence Research Group established a Research Study Group on 'Manpower reduction in shipboard systems' (16) and the subsequent adoption by NATO of a procedure for establishing ships' complements. Furthermore, a wide range of

technologies has been used, or proposed, as means of reducing ships complements. Starting in the 1970s there have been many attempts to reduce crewing levels through changes to policy, procedures, practice and the application of new technology and through the development of modelling and simulation capabilities to study crewing.

While studies on crewing reduction have been carried out in Canada, as well as in The Netherlands, UK and USA, the CF appears to have taken less direct action to reduce crewing levels. For example, while the CPF acquisition implemented technologies such as SHINPADS, SHINMACS and SHINCOM, the complement requirements for the CPF were that the ships be designed for a two-watch system (as per a policy established by the ADM Personnel MORPS study), that they have similar skills and watch-bills to existing ships, and that the number of crew be not more than that of the DDH 280 class. As for research and development, it has focussed on naval sensor and platform system technologies. The 1994 DMSS recommendation to the naval research and development committee that identified the need for research in a range of topics related to crewing reduction was ignored in favour of other priorities.

The adoption by Canada of some technologies, such as the switch from steam to gas-turbine propulsion or the adoption of canister weapons, has reduced crewing requirements (17). Such 'incremental savings' are typical of an 'evolutionary' approach to crewing reduction, as shown in Figure 4, reproduced here from Reference 13 When there has been a steady progression of ship classes, as happened in the Royal Navy and Royal Netherlands Navy from the 1960s to the 1990s, then the evolutionary approach has lead to a slow but steady decrease in crewing requirements (18). Only by taking a revolutionary approach, linking crewing requirements with a Human Systems Integration process that is in turn linked with the Systems Engineering effort can revolutionary reductions be made in complements. This was the impetus for the US Navy's SC/ DD-21 project. However, new classes of ship may not achieve more than incremental crewing reductions compared with predecessors unless a determined effort is made to do so. This is because ships are usually assembled from 'off the shelf' sub-systems, each of which has its own implications for operator workload that, collectively, establish the requirements for crewing.

As well as focusing on the systems design process to achieve clearly stated complementing goals, the US Navy is investing in research that may achieve revolutionary reductions in crewing requirements for areas such as Damage Control and Firefighting, Operations Room activities, and Replenishment At Sea. Without the investment of research effort in those areas it is doubtful if industry would undertake the necessary R&D.

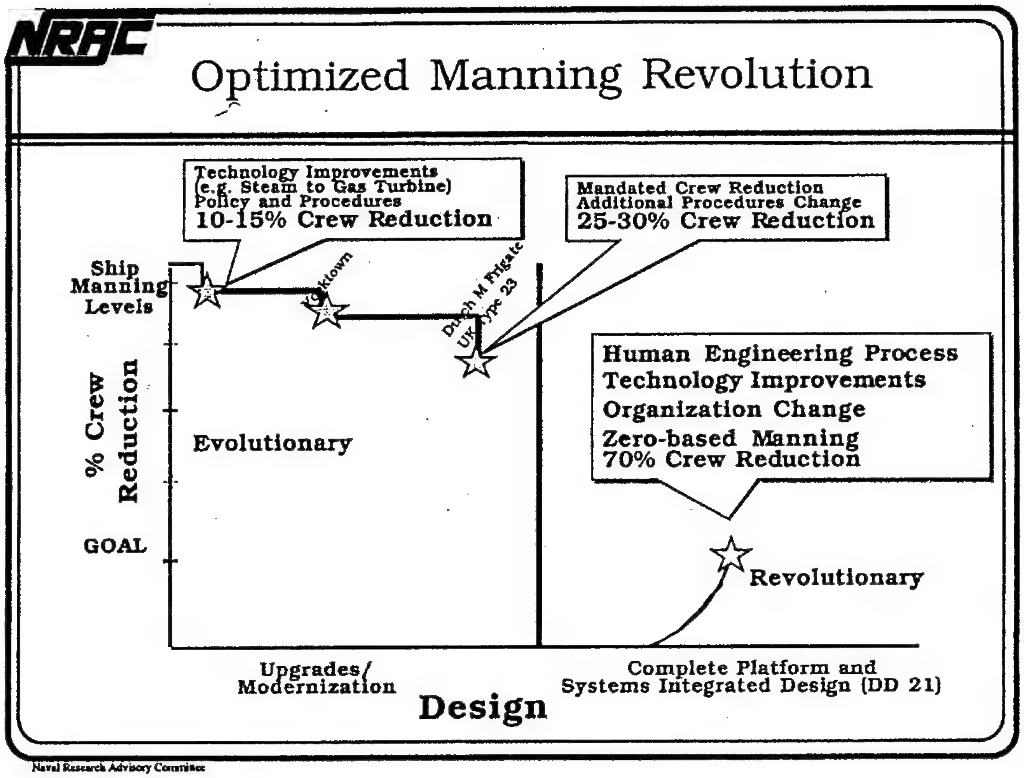

Figure 4. *Evolutionary vs. Revolutionary approaches to crewing reduction*

3.3 Applicability to Canadian naval ships

In Canada, new ship classes are so infrequent that the evolutionary model offers little scope for significant reductions in personnel requirements. At the same time, the revolutionary approach can only be applied to new ship builds, few of which are foreseen. Given these constraints, and given that many ships' complements are already under strength, the potential for the Canadian Forces to realize significant reductions in personnel requirements for crewing its ships is very limited. The two new ship classes being initiated (ALSC and CADRE) provide opportunities to investigate revolutionary changes and to manage those changes during the ships' life cycles through an established complementing process in DND. To do this, a complementing and Human Systems Integration process would have to be established quickly within those projects in order to take advantage of the project timelines.

The material collected and catalogued in the first phase of the study is, if not exhaustive, at least representative of the range of possible technologies for crewing reduction. It is much more difficult to comment on the applicability of each of the technologies to Canadian ships because very little information was obtained to provide

the context for judging their applicability. For example, some of the developments made by the US Smart Ship project, such as the implementation of centralized machinery monitoring systems and standard console systems, exist as Canadian technology such as SHINMACS and SHINPADS[3]. However, the extent to which the recent US Navy installations have achieved crewing reductions compared with the CPF and TRUMP systems is not known because we were unable to obtain information on the assignments of personnel or what are the high workload and complementing demands on Canadian ships, either currently in service or being planned. In the absence of such information is it impossible to review the potential of any technology for reducing workload or crewing in other than the most general terms, as was made clear by the participants in the focus groups and technology evaluation workshops.

The ratings of applicability produced by the two workshops (figures 2a, b) suggest that all are potentially applicable to Canadian naval vessels. (While it would have been preferable to have the various technologies rated by more naval experts, the standard deviations of the ratings suggest that there was a high level of agreement among the raters). The applicability of the various technologies to Canadian naval vessels will depend on the advantages and disadvantages of each potential solution, many of which were cited by the focus groups and POCs. Solutions in some technology clusters may conflict with others in the same or in different clusters. For example, the cluster 'Modifications to Crew Structure' includes 'Combine or Eliminate Existing Trades', 'Flatten the Rank Pyramid' and 'Assign Lower Ranks.' The latter results in lower personnel cost; it does not necessarily result in lower complements. Assigning lower ranks, which was implied in the 1978 MORPS study, includes staffing so that senior personnel are not used for jobs that can be done by junior personnel. It also includes reducing the skill requirements of jobs, whereas reducing crewing generally removes the lower personnel with low-level skills and therefore increases the costs per individual.

Other technologies may require changes in policy. For example the adoption of wireless communications that the US Navy's Smart Ship programme has used to reduce crewing are viewed by some CF personnel as compromising the ship's EMCON capability. The importance of the need to change policy to support workload and crewing reductions was noted in the lessons learned.

Some technologies may require changes to the supporting infrastructure. For example, several reviewers expressed concern about the communications bandwidth required to implement technologies such as virtual presence, teleoperation and condition-based monitoring.

Other technologies have implications for future skill sets, particularly given the current scarcity of Information Technology skills and experience in the CF. Furthermore,

[3] (A CAE Inc. machinery control system was installed on the first Smart Ship, USS Yorktown, CG-48, but the company lost the bid to provide similar systems for subsequent class-wide installations. An oil analysis system produced by GASTOPS Inc. is being implemented as part of the US Navy's Capital Investment for Labor project.)

automation, in whatever form, replaces the lowest levels of operator skills. A revolutionary reduction in ships' complements would probably change the current rank pyramid into a pentagon, with less crew at the lowest rank levels than at the intermediate ranks levels. This will require major changes to current practices for the recruitment, selection, training and career management of personnel. Skill sets available from industry will also become important. Both Dr. R. Morchat of DREA Dockyard Labs and Ms S. Pecman, the DMSS expert on finishes, expressed reservations about the current ability of Canadian industry to meet the quality assurance requirements for the application of low maintenance finishes. Project personnel reviewing these technologies should review the advantages and disadvantages documented in references 3 and 4 of this report.

The applicability of the various technologies must also be evaluated in the context of challenging scenarios and ship evolutions and both the primary, secondary and emergency tasks for relevant crewmembers. As the focus groups made clear, removing crewmembers on the basis of their primary tasks can have significant effects on the performance of secondary and emergency tasks. At the same time, during the workshops to rate the applicability of the technologies, several solutions were dismissed by the argument that "they [the crew who perform the task currently] are on the ship for other reasons." Given that all crew have primary and secondary duties if this argument were taken to the extreme it would preclude any change. Therefore the technologies should also be reviewed in the context of a reduced manned ship. For example, both food preparation and CASEVAC requirements may reduce with changes in complement and ship design, so the needs for stewards should not be based on current numbers.

The many factors and interactions outlined above make it difficult to arrive at a solution in terms of an overall ship's complement. To determine the optimal mix of technologies (all of which are potentially applicable) and personnel, each ship class must be evaluated using a systematic analysis based on the full range of scenarios, missions, concepts of operation and support, and the range of technologies proposed for the class. A series of 'successive approximations' will be required to produce a solution, based on a model of necessary crew tasks and task demands drawn from challenging scenarios. Complementing simulation models such as the RN's CREW II and the Australian Ship Resource Simulation Model must be examined for their potential to reflect primary, secondary and emergency duties in demanding scenarios. If necessary improved models should be developed. Once the potential for changes in crewing has been identified, DND must be prepared to work through all of the changes that will be implied in the areas of recruitment, personnel selection, training Quality of Life and career management.

Finally, as the review of lessons learned, advice from US Navy experts, and the experience of participants in the focus groups made clear, any programme to reduce workload or complements must be matched by efforts to change the current culture.

3.4 What can the Canadian navy do to reduce crewing costs?

From the material reviewed, particularly the lessons learned from other programmes, it is clear that several critical requirements must be met if the various technologies that have been identified are to be applied successfully to reducing workload or crewing on Canadian naval ships. In the most general terms, the navy must become much better informed about workload and crewing issues, compile valid statistics on its operations and continue to gather information on crewing reductions that have worked in other navies, including :

- the areas of high workload and crewing demand on existing and future ships must be identified (only from an understanding of the workload and crewing 'peaks' or 'labour cost centres' can the applicability of the various crewing reduction technologies can be assessed),
- the workload and crewing requirements of candidate technologies must be identified. This will require effort to compile information on the skill, training and workload requirements for individual ship sub-systems,[4]
- models should be developed of the primary, secondary and emergency duties and tasks for current and new ships, to allow experts to work though all of the implications that changes in crewing have for duties and tasks, personnel backup, supervision and training as well as for Recruitment, Personnel, Training and Detailing, Quality of Life, and the Sea: Shore duty ratio,
- a complementing process should be initiated (this technology received the highest ratings in the evaluation workshop; as noted in the conclusions of the workshop report the current complementing process is to rely on contractor estimates of personnel requirements),
- a process for human systems integration that is linked to the complementing process, and to the ship requirements development and design process should be implemented,
- to support cost-effectiveness studies, the costs and capabilities of the various navy ranks must be identified,
- the capability of Canadian industry to implement the various technologies should be examined.

To do this, DND needs to establish a complementing capability. This capability must be based on a solid process and be supported by a mix of personnel, for example: a

[4] (At the start of the Continuous Acquisition and Life-Cycle Support (CALS) project, it was suggested that the product information should include personnel and skill requirements for operation and maintenance. That suggestion seems to have been lost in the change in emphasis to standards for the transfer of product information.)

senior officer, a senior NCM, an expert in Human Systems Integration, an expert in costing, and an expert in personnel and career management. This team of personnel could at minimum be 'virtual' with existing personnel throughout headquarters being linked as a complementing advisory team with permission to spend part of their day on this activity, but optimally this capability would exist as a dedicated team. The team should have two streams of activity; one stream supporting existing ships and one supporting new ship builds. If, because of cost or human resources limitations, such a capability and a team cannot be established, then it is unlikely that much progress will be made in addressing what is a very complex problem. All change requires the application of effort of some sort.

For current ships the navy must determine the high personnel cost centres (high crew cost areas) and those crew functions and tasks which are currently not being completed due to crew shortages (workload concern areas). Towards the end of the current project, the authors were informed that MARFLTLANT has been conducting an ABC study. The ABC study was originated in HMCS ST John's and has now been expanded to four other ships. Information from the study may provide some insight into how and where sailors' time is being spent. The authors were also informed that CPF and TRUMP projects were required to provide life cycle personnel costs and that the information should be in the archives.

The little information that has been obtained on operations aboard Canadian ships suggests that the highest priority should be assigned to maintenance and husbandry. Candidate technologies to address these concerns should then be selected and additional focus groups run with fleet experts to identify the most promising candidate technologies. These candidate technologies should then be evaluated using a systematic complementing analysis that evaluates the impact on primary, secondary and emergency functions and tasks performed by the affected personnel. This work could be completed by a complementing analysis, conducted in-house if the capability were established within DND or undertaken by contractors. As the work would involve some form of model based analysis the activity may benefit from liaison with the evolving modelling and simulation offices within the Directorate of Joint Force Development.

For future ships currently in the Identification or Options Analysis phase (ALSC and CADRE), a complementing capability and associated human systems integration process should be made part of their scope immediately. This is supported by all inputs to the study including the literature reviews, interviews with the US NAVSEA personnel, focus groups with fleet staff, and workshops with headquarters staff. If a complementing process is inserted into the ALSC and CADRE acquisitions, then this process could flow back into DND with personnel to support it as these vessels are delivered over the next 5 years – as a minimum this is required to ensure that the complement of these lower crewed ships is managed properly over their life cycle.

PMO ALSC is about to release contracts to industrial teams that will go through a definition/preliminary design phase. This phase is the 'now or never' opportunity to apply a complementing process that has a chance of making the changes required to affect a revolutionary (larger than 10 to 20%) reduction in crew size. Statement of

Work elements must be written to ensure that the proper process is followed and integrated within the overall design and development process, and the PMOs should obtain Human Systems Integration support to their team to provide oversight and support to this high priority activity. DSTHP took the initiative to make material on the HSI process available to DND. That material needs to be tailored to the ship acquisition process. The Human Systems Integration project run by DSTHP can assist in the provision of this support in the same way that it does for the Maritime Helicopter Project (MHP), a recommendation that is supported by DMSS 2-organization. A Statement of Work for the necessary support is attached at Annex E.

3.5 How can DRDC contribute to crewing reduction?

This study has been jointly sponsored by DSTM and DSTHP, drawing on the latter's Human Systems Integration technology base. Future DSTHP activities on crewing reduction will be limited because they are only part of a comparatively small research Thrust conducted within Client Group 6 as part of a 'purple' research programme. Client Group 1 should be able to sponsor a more significant level of research and development. Both short-term and long-term research and development activities can be identified from the results of this study.

In support of the ALSC and CADRE projects, a study should be conducted of how to express the requirements for the various crewing reduction technologies as Statements of Requirements and as activities in a human Systems Integration effort within a ship development project. This would assist project teams in understanding how to include the technologies in their acquisition documents, so that, if studies indicate that they should be implemented, the teams could systematically do so. To deliver such input in a useful fashion it is recommended that a team organize and express the technologies as requirements statements in a DOORS database with traceability links back to the sources, as this would provide an easily accessible list of requirements for the projects who use the DOORS tool for their SORs and Specifications. Such a study would draw on information provided by TTCP HUM TP-9 and support KCAs 2 and 3. A Statement of Work for such a study is attached at Annex E.

Once the high labour cost areas of current ships have been identified, the list of Crewing Reduction Technologies that require further development will provide a basis for the Maritime R&D Overview Group (MRDOG) to examine where the research and development programme might contribute to crewing reduction. The high ratings of applicability to current ships that were given to 'Decision Support Systems' support the current research effort in Thrust 1ba. Other logical choices for research and development would build on Canadian successes, such as SHINMACS and SHINCOM and the condition-based maintenance technology of companies such as GasTops. In addition to possible further developments of these technologies, DRDC should collaborate with ship concept development teams to explore applications of these technologies and should explore with industry how the various technologies can be applied.

In addition, DRDC should support the development of improved models for simulating crew complements. Existing models such as the ERASMUS complement analysis software developed by DMSS and the complement simulation models such as the RN's CREW II and the Australian Ship Resource Simulation Model should be examined for their potential to reflect primary, secondary and emergency duties in demanding scenarios. If necessary improved models should be developed.

Another possible line of research would be to investigate how group cohesion and leadership issues could be integrated into a Human Systems Integration driven complementing analysis using role and task based modelling tools. This is an important dimension raised by the operations community. Projects 11ba26 and 16ka could provide the basis for reviewing research on group cohesion and leadership. Task based modeling tools being developed in Project 16kc could be used, if additional funds were provided to implement changes in commercially available task network modelling software.

In the longer term, DRDC, through DSTHP and DCIEM should continue participation in TP-9. Areas of relevance to crewing reduction include: UK and US efforts to develop an improved technique for allocating functions to humans or automation; US efforts to develop improved RAS systems, and; the US Multi-Modal Watchstation development which the UK is now implementing for R&D purposes and which has been shown to reduce watchstanders in the US Aegis class CIC from 9 to 5 (19).

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4. Conclusion and recommendations

The aim of this study was to conduct a relatively quick assessment of crew reduction technologies. Study goals were to:

1. Catalogue (list) the information already available from past and current studies on the crewing of warships,

2. Assess the applicability of this work to Canadian Naval vessels (including logistic support vessels) and

3. Recommend a way forward leading to the implementation of a reduced crewing strategy for Canadian naval ships.

Over two hundred references from the scientific and technical literature and the world-wide-web show that a wide range of technologies available to support crewing reduction. The deliverables for the first goal are a matrix of the references and abstracts to technologies and a list of 29 clusters of those technologies. These deliverables are available on the HSI Special Projects section of the DRDC web site on the DWAN and the Internet.

The study TOR also required the identification of the deficiencies in available information. The chief deficiency that was identified was information on the current state of workload and crewing and the associated costs on Canadian naval ships. No quantitative information was obtained on the pattern of crewing or workload (the 'high demand' tasks) on existing or future ships. Without such information and a model of primary, secondary and emergency tasks for a range of operational scenarios the applicability of these technologies to Canadian navy ships can be commented on only in terms of their potential. From the opinions and ratings provided by four focus groups and two workshops with navy Points of Contact it is concluded that all of the 29 clusters of technology are potentially applicable to Canadian naval ships although there are differences between ship classes. Actual applicability will depend on a thorough review of the advantages and disadvantages of each technology and the current operational context. Given the current state of crewing, the application of such technologies is likely to contribute to reducing the excessive workload that many crew currently experience due to ongoing crew shortfalls rather than to further reductions in complement.

Successful application of any of the workload or crewing reduction technologies will be achieved only if all of the effects on primary, secondary and emergency tasks are worked through in all likely scenarios and for the full scope of personnel issues, including crew rotation from sea to shore, backup for crew missing due to sickness, leave or training, and time spent at sea or with families. Other necessary conditions for successful application include: changes in policy and procedures; changes in the

approach to recruitment, selection, training, complementing, and career management; a process for establishing reduced complements based on a Human Systems Integration process, and; successive iterations using complement simulation models and experimentation in an atmosphere that tolerates initial failure.

The deliverables for the second goal of this study are the reports on the focus group sessions and technology review workshop reports that are available on the HSI Special Projects section of the DRDC web site on the DWAN and the Internet.

From the foregoing material a way forward was developed for Canadian applications. It is recommended that:

- the navy establish its own capability in workload and crewing reduction, supported at the highest levels;
- that capability be provided by a team of specialists dedicated to studying the application of crewing reduction technologies;
- the efforts of this team be supported by efforts to change the current culture with respect to crewing and workload;
- the workload and crewing reduction team conduct a study to identify where crewing effort is expended on current ships and where insufficient effort is available with current crews,
- the team then use that study to evaluate the costs and benefits of applying the crewing reduction technologies identified in this study and iterate potential solutions using simulation models of ships' complements and crew tasks;
- a parallel study be completed to define exactly what operational tasks each class of ship is expected to accomplish using its own resources, what supporting resources, such as an FMG, are required and how such resources can be maintained over time;
- a complementing capability and associated HSI process be made part of Identification, or Options Analysis phases of ALSC and CADRE projects;
- MRDOG study the list of technologies requiring further development to identify where significant contributions might he made based on the current research programme and Canadian developments such as SHINCOM, SHINMACS and condition-based maintenance technologies;
- MRDOG review how DND and DRDC might collaborate with Canadian industry to develop the capability to apply the most promising crewing reduction technologies;

- CG 1 supports Human Systems Integration aspects of naval technologies, specifically in the evaluation of existing crewing simulation models and the techniques for expressing the technologies reviewed in this study as Statements of Requirements for new systems

- DSTHP and DCIEM continue their involvement in TTCP HUM TP-9 and seek ways of exploiting UK and US developments available through the Panel.

The above recommendations and this report are the deliverable due for the third goal of the study.

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Annex A: Terms of reference of Phase 1 of reduced crewing technologies study

1.1 Background

1. The LCM cost of operating warships is heavily influenced by the cost of paying personnel to operate them. Modern materials and automation technologies would appear to offer a way to reduce personnel costs while maintaining the ability to operate and fight the ship.
2. Several navies have already conducted studies of this issue, looking carefully at career development and training issues as well as the more technical matters. The topic is also a subject for ongoing research in several national and international fora.
3. DGMDO has requested that a study be carried out to determine what can be done in the Canadian context. At the Maritime Research and Development Overview Group meeting held on 20 November 2000, it was agreed to begin the study with a relatively quick assessment of the situation and report back to the Group by about 1 June 2001.

1.2 Aim of study

The aim of this first phase of the study is to:

- catalogue (list) the information already available from past and current studies on the crewing of warships,
- to assess the applicability of this work to Canadian Naval vessels (including logistic support vessels) and
- to recommend a way forward leading to the implementation of a reduced crewing strategy for Canadian naval ships.

1.3 Conduct of the study

1. Mr. David Beevis of DCIEM, supported by DSTHP and one or more contractors, as appropriate, will manage the study. In the event that further guidance is required during the context of this study, DSTM will be consulted.

2. The study manager and/or team will consult suitable representatives of the following organizations in order to gain a full cognisance of the issues that need to be considered and to identify related studies, both past and ongoing.

Organization	Individual Rep.
DMMCP	Capt(N) J. Pickford
DMPPD	LCdr M. Tunnicliffe
D Mar Strat	Capt(N) D. McFadden
DMSS	Mr J. Menard
MORT	LCdr P. Massel
DSTM	Mr Orest Bluy
DNPP	Cdr S. Allaire
DNPR	Cdr W. Riggs
DSHRC	Dr. A. Jesion
DMMPP	LCdr R. Houle
DSTHP	Dr.A.L. Vallerand
DREA	Dr. R. Morchat

3. The Study will report the information already available and the deficiencies of available information under the following general headings:

Strategies applicable to the immediate reduction of personnel numbers with no investment required in modification to ship systems or support infrastructure (could be implemented through currently funded maintenance and training programs).

Strategies applicable to the immediate reduction of personnel numbers with minor changes to ship systems or infrastructure (could be implemented through minor augmentations to currently funded maintenance and/or training programs)

Strategies applicable to existing ships through significant investment (could be implemented through mid-life or other major refit opportunities, with associated changes to training and/or programs).

Strategies applicable to ships of new construction.

Strategies requiring further development prior to implementation.

4. A draft report will be circulated to and discussed with the points of contact identified in para 6 prior to publication of the final report.

5. This phase of the study will be completed by 1 June 2001.

Annex B: US Smart Ship Project technologies

(From Bost, 1996), Technologies were implemented to improve the following:

Communications – high frequency radio group, fleet broadcast update, wirefree communications, Fibre-optic LAN;

Crew Support – automated division officer's notebook, consolidated and reduced documentation, Smart ID card;

Maintenance – corrosion control, Reliability Centred Maintenance (RCM);

Bridge Systems – Chart inventory system, navigation system interface, Integrated Bridge System;

Engineering – Reduced manning in engine room and auxiliary spaces, reduced signalman watch manning, integrated condition assessment system,

Damage Control – firefighting equipment, upgraded breathing apparatus, computerized damage control system;

Combat Systems – CIWS upgrade, Command Doctrine decision aid, Computer-aided dead reckoning, Mk 46 Mod 1 Optical Sight, Sonar capability upgrade, Ring laser gyro, peripheral Equipment Emulator system;

Topside Watch Reduction – Pilot house manning reduced from 12 to 5, bridge messenger eliminated, combat systems maintenance watch manned only when necessary, radio central watch standing;

Supply – Bar-coding for supplies, cashless services, plastic waste processor, large waste pulper;

Crew Support – Galley operations improved, zero-based review of PQS requirements, streamlined stores distribution, all hands clothed in coveralls;

Manpower – use existing manpower analysis tools to determine differences arising from Smart Ship changes

Information – Install SNAP III common data system, expand number of phone lines on the pier;

Engineering/ Damage Control – STAR low pressure air compressor with expert diagnostics, revers osmosis distillation units, standard monitoring and control system;

Deck Operations – Deck crane to replace block and tackle, platform elevator to replace torpedo strikedown system, improved rigging and winch procedures for replenishment, laser range finding display for underway replenishment;

Administration – Voice recognition technology for display control, data entry, information feedback, Windows-based software for all engineering programs and logs.

Annex C: Workload and Crewing Reduction Technologies Literature Matrix

Overview:
This information summarizes the research to date regarding technologies that can be applied to reduce crew workload, complement or associated crew costs. The literature summary matrix organizes the 100+ technologies identified according to:

1. Ship Function
2. Personnel and Training
3. Policy and Procedures
4. Human Systems Integration

Within these groups the crew reduction technologies are then categorized in one of five columns across the matrix:

1. No Cost. Technologies that can be used immediately with no investment required in modification to ship systems or support infrastructure (could be implemented through currently funded maintenance and training programs).

2. Low Cost. Technologies that can be used immediately at minor cost to ship systems or infrastructure (could be implemented through minor augmentations to currently funded maintenance and/or training programs)

3. Major Cost or Ship Alt. Technologies that can be used on existing ships at significant investment (could be implemented through mid-life or other major refit opportunities, with associated changes to training and/or programs).

4. New Construction. Technologies best suited to future ship designs.

5. More R&D Required. Technologies that require further development prior to implementation.

Cost - Benefit:
No information was obtained that identifies what areas of Canadian ships cost the most in terms of personnel (i.e. "the cost centres"). Research to date on this topic indicates:

1. Current crewing for HFX consists of 30 officers; 52 C & POs; 156 MS & below. This is an increase of 12 from the CPF. Major personnel demand areas are ship-level tasks – damage control, RAS, storing, and husbandry (Menard 1997).
2. Research in the Netherlands indicates that RAS and damage control are the high personnel drivers (Essens, 2001).
3. A US study concluded that reduction of watch stations is the key to reducing crew in the 120 – 160 range; to go below requires changes in maintenance philosophy, support and administrative functions. (Dent 1999).
4. UK-US Project Workshop on Technologies for Optimized Manning agreed that major technologies for personnel reduction are (1) HSI and human centred design, (2) Top-down function allocation and crew modelling, (3) Advanced decision support and information management, (4) Simulation based: training / recruitment screening' skill

assessment, (5) High performance distributed computing, (6) Condition-based monitoring and control, (7) Collaborative planning and interoperability issues, (8) Net-centric warfare/ force data fusion/ bandwidth issues, (9) New materials, coatings. (Masakowski 2000).

Literature Summary Matrix:
The following matrix summarizes the technologies to date. Each technology is listed as numbered below the table. Selecting the term "*Refs*" throughout the technology list links to the complete reference and abstract list.

	No Cost	Low Cost	Major Cost / Ship Alt	New Construction	Further R&D Required
1. Technologies Focused on Ship Functions					
Applicable Across All Functions			1. Top-down Decomposition of Ship Functions.		
Executive and Administration	2. Move Admin Tasks Ashore. 3. Consolidate Instructions and Information.		4. Smart ID Card. 5. Electronic Manuals.		
Seamanship		6. Low Maintenance Paint. 7. Hand Tools.	8. Change Equipment Location on Bridge. 9. Voice Recognition to Replace the Helmsman. 10. Bridge EO Systems. 11. Commercial Mooring Lines and	14. Develop Integrated Bridge. 15. Reduce Requirement for RAS. 16. Corrosion Minimizing Materials. 17. Enhanced Ventilation Systems	

	No Cost	Low Cost	Major Cost / Ship Alt	New Construction	Further R&D Required
			Winches. 12. Video Surveillance Systems. 13. Improved RAS & UNREP Equipment		
Command and Control			18. Multi-Modal Watch Stations.	19. Integrated Command Environment	20. Decision Support Systems.
Combat Systems Engineering			21. Fire & Forget Weapons	22. Redundant Systems	23. Integrated C3I 24. Virtual Presence – C3I
Marine Systems Engineering		25. Calibration Reduction.	26. Systems Health Monitoring 27. Condition - based maintenance. 28. Automated On Board Oil Analysis 29. Tank Monitoring Systems 30. Sealed Bearings 31. Mechanical Seals 32. Electronic Technical Manuals.	16. Corrosion Minimizing Materials. 17. Enhanced Ventilation Systems. 22. Redundant systems 33. Electric propulsion. 34. Highly Reliable Systems. 35. Self-Configuring Systems. 36. Integrated Machinery Control. 37. Smart Sensor and Actuator	40. Robotics 41. Advanced Power Systems - Electrical. 42. Advanced Power Systems -Fuel cells 43. Wear-Resistant Materials. 44. Advanced Lubrication Systems 45. Advanced Micro-Mechanical Systems. 46. Ice Slurry for Cooling: 47. Advanced Machinery Control

	No Cost	Low Cost	Major Cost / Ship Alt	New Construction	Further R&D Required
				Technology. 38. Intelligent Machinery Monitoring & Diagnosis. 39. Maintenance Management System	48. Advanced Machinery Monitoring & Diagnosis. 49. Virtual Presence - Maintenance
Logistics			50. Automated Teller Machines 51. Improved Food Services 52. Virtual Presence - Medicine 53. Improved Husbandry. 54. Waste Treatment Systems	55. Cargo/ Stores Handling.	56. Enhanced Mission Electronics. 57. Automated Shipboard Food Service.
Damage Control and Emergency Response			58. Damage Control Support Systems.	22. Redundant Systems 59. Reduce Requirement for Damage Control. 60. Integrated Platform Control 61. Automatic Fire	63. Damage Control Automation.

	No Cost	Low Cost	Major Cost / Ship Alt	New Construction	Further R&D Required
				Detection and Suppression Systems. 62. Unmanned Spaces	
Air Operations					64. Unmanned Aerial Vehicles
Total Ship	65. Contract-Out Support Functions. 66. Eliminate cumbersome work practices	67. Smart Ship Technologies 68. USN Capital Investment for Labor solutions 69. Well Deck Overheads 70. Preservation Teams 71. Hydroblast Systems	72. Re-Allocate Functions and Tasks 67. Smart Ship or Commercial Technologies 73. Wireless Internal Communications and Fibre Optic LAN 74. Change equipment location 76. Watertight Door Maintenance Reduction	75. Manning Requirements Analysis. 76. Design Process Including the Human Element 77. User-Friendly Man-Machine Interfaces 78. Advanced Design Techniques	79. Advanced Computer Operations Support Systems. 80. Thin Server Technology 81. Improved Crewing Predictions.
2. Technologies for Personnel & Training					
General			82. DRDC Junior MARS	84. Develop New Manpower	85. Advanced Training Technologies

	No Cost	Low Cost	Major Cost / Ship Alt	New Construction	Further R&D Required
			Trainer 83. US TOM Training Technologies	Personnel and Training Structure.	
Manpower and Personnel	86. Flatten Rank Pyramid. 87. Combine or Eliminate Existing Trades. 88. Assign Lower Ranks			89. Create New Multi Role Trades.	
Training	90. Train Alongside.	91. Enhance Training Technology		92. Embedded Training	93. Tailored Training
3. Policy and Procedure Technologies					
Complementing Practice		94. Improved Crewing Management	95. Manning Optimization Process.	96. UK Complementing Practice. 97. Manning Directorate.	98. Organizational Commitment to Crewing Reduction. 99. Optimized Detailing. 100. Cost Management.
Operational and Support Concept	101. Man for Missions 102. Change Standards 103. Alter Sea-to-Shore Ratio.	105. Core and Flex Watch Systems.	106. Disassociate Crews from Hulls	107. Limit functions	108. Limit missions

	No Cost	Low Cost	Major Cost / Ship Alt	New Construction	Further R&D Required
	104. Change watch systems.				
Procedure Structure	109. Sequence Functions (evolutions).			110. Type 23 Procedure Experience	
Supervision & Leadership	111. Increase Productivity.				112. Advanced Practices for Getting Best out of Crew.
	4. Human System Integration Technologies				
General			113. Human Systems Integration process	113. Human Systems Integration process 114. Modelling of Ship Tasks 115. Analysis of Tasks.	116. HSI Tools 117. Techniques for Modelling Team Activities.

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6. Technology descriptions

The research summarized in the literature identified a number of technologies that can be used towards the reduction of personnel on naval vessels. These technologies are very briefly described in the list below, with some indication of the source papers (this information is still being consolidated, with a more complete description of each technology in the project report). As summarized in the literature matrix, these technologies include:

1. **Top-down Decomposition of Ship Functions.**
   Conducting structured analysis of ship functions by completing top down decomposition, and then completing function analysis and allocation allows functions to be automated, consolidated, simplified, or eliminated.

2. **Move Admin Tasks Ashore.**
   Moving administrative tasks off the ship to shore based offices.

3. **Consolidate Instructions and Information.**
   Reduce the volume of instructions and information that has to be processed by the ship crew (eg: US Smart Ship cancelled 118 instructions and consolidated information into 4)

4. **Smart ID Card**
   Deploy multi purpose identification cards for use throughout the ship, combined with readers such as the Smart Ship Multi-technology Automated Card Reader – MARC.

5. **Electronic Manuals**
   Convert or create manuals in electronic format for lower maintenance and easier access by all ship personnel. Smart Ship technologies included a Chart Inventory System.

6. **Low Maintenance Paint.**
   Apply paint that requires less frequent maintenance.

7. **Hand Tools**
   Procurement and distribution of state-of-the-art hand tools will allows crew to prepare surfaces more effectively and apply coatings with more ease.

8. **Change equipment location on Bridge.**
   Alter the arrangement of bridge displays and controls to allow fewer personnel to efficiently complete the same functions.

9. **Voice Recognition to Replace the Helmsman.**
User voice recognition technology to replace the helmsman, such that the same commands can invoke the same responses without the need for that human role.

10. **Bridge EO systems**
Electron-optical systems such as the DREV SEOS project

11. **Commercial Mooring Lines and Winches.**
Use commercial standard mooring lines and winch systems to reduce personnel requirements when berthing (e.g.: "Steelite" lines and handling equipment).

12. **Video Surveillance Systems**
User video systems to assist with ship handling to reduce need for personnel when manoeuvring ship, keeping lookout, etc.

13. **Improved RAS & UNREP Equipment**
Implement enhanced replenishment equipment that can be operated with fewer personnel. Smart Ship examples include CONREP Connect Up Rigging Winches and Procedures, and the use of Laser Range Finders with Displays.

14. **Develop Integrated Bridge.**
Install commercially-develcoped integrated bridge systems and equipment that require less personnel.

15. **Reduce the Requirement for RAS.**
Develop ships with lower RAS requirements and subsequent need for personnel.

16. **Corrosion Minimizing Materials and Preservatives.**
Employ corrosion resistant materials, and preservatives.

17. **Enhanced Ventilation Systems**
Reduce corrosion in ventilation systems by using: teflon coatings on the suction side, improved disposable filters; zip-off cloth ducting used by Royal Navy; a moisture separator/filter in main machinery and auxiliary space supply ventilation; extending

18. **Multi Modal Watch Stations.**
Use multi-modal watch stations that integrate a range of sensor and tactical information in combined visual and auditory display systems, shared by a reduced number of users in the operations area.

19. **Integrated Command Environment.**
Develop collaborative command rooms with Multi Modal Watch Stations and shared overview displays, as demonstrated in USN ICE Lab environment. A Smart Ship example includes the Navigation Sensor System Interface.

20. **Decision Support Systems.**
Implement Artificial Intelligence and Decision Support Systems to reduce the number of front row operators in operations rooms. Examples include US/UK TOM references DIEHRD, MACE, SI, ATRI, Computer Aided Dead Reckoning.

21. **Fire and Forget Weapons.**
Utilize fire and forget weapons allowing fewer personnel to process more threats.

22. **Redundant Systems.**
Deploy redundant combat systems, reducing personnel requirements for both combat and front line support in this area.

23. **Integrated C3I**
Create, control, communications, and intelligence (C3I) systems that are more integrated, allowing less personnel to process more intelligently fused combat information.

24. **Virtual Presence – C3I.**
Have key C3I personnel, such as the Admiral and staff, linked by telepresence and groupware (collaborative software).

25. **Calibration Reduction**
Elimination of time consuming and labor intensive calibration recall through complete review of requirements, elimination of excess requirements and conversion of valid requirements to PMS; US Smart Ship Reliability Centred Maintenance Based review of Planned Maintenance Requirements.

26. **Systems Health Monitoring.**
Deploy sensors and associated computer monitoring software to monitor the health of the ship systems, reducing the need for personnel to patrol and continually check the status of these systems.

27. **Condition Based Maintenance.**
Switch to condition based maintenance (respond to areas that require maintenance as alerted by system health monitoring system) as opposed to preventative maintenance to reduce personnel conducting maintenance and to reduce breakdowns initiated through preventative maintenance. An example Smart Ship technology is the Integrated Condition Assessment System or ICAS.

28. **Automated On-Board Oil Analysis: COTS** (Gas-Tops, Canada)
Automated monitoring for in line wear debris and oil quality will replace the current labor intensive oil analysis (combination of onboard testing and ashore lab analysis).

29. **Tank Monitoring Systems**
Tank monitoring systems that measure tank corrosion by monitoring changes in electric potential will help eliminate condition-based inspection and cleaning (as opposed to cleaning at regular intervals).

30. **Sealed Bearings**
Replacement of open face bearings with shielded, sealed bearing on five horsepower and below motors will eliminate the need for periodic maintenance on the bearings and reduce the associated hazardous material (grease) stowage aboard ship.

31. **Mechanical Seals**
Improved COTS mechanical seals for pump applications have a simpler design, require less labor for installation and replacement and have a longer service life. These use split seals that do not require the whole pump of motor to be dismantled for replacement (2 hrs vs. 48 hours).

32. **Electronic Technical Manuals.**
Technical manuals in electronic form to reduce maintenance requirement and ease access throughout ship.

33. **Electric Propulsion.**
Electric propulsion systems require lower maintenance and common skill sets.

34. **Highly Reliable Systems.**
Utilize only highly reliable systems to reduce maintenance requirement (e.g.: Gas turbines in lieu of diesels).

35. **Self Configuring Systems.**
Utilize self-configuring systems (such as electrical systems), with computer based monitoring and control.

36. **Integrated Machinery Control.**
Integrated machinery control that one or two personnel can operate and monitor from fewer, integrated, workstations.

37. **Smart Sensor and Actuator Technology.**
Utilitize smart sensor and smart actuator technologies throughout the ship systems, allowing logic for operator to be integrated into monitoring and control software.

38. **Intelligent Machinery Monitoring and Diagnosis.**
Sensor and computer systems to monitor the status of machinery, diagnose off normal states, and advise the user on status or potential required maintenance.

39. **Maintenance Management System**
Management system to plan and manage on board maintenance.

40. **Robotics**
Implement robotics to support marine systems monitoring and maintenance.

41. **Advanced Power Systems – Electrical**
Implement advanced electrical power systems requiring less monitoring and maintenance, and common skill requirements with other systems for operation.

42. **Advanced Power Systems – Fuel Cells**
Implement advanced fuel cell based power systems requiring less monitoring and maintenance.

43. **Wear Resistance Materials – Machinery**
Utilize wear resistant material in machinery systems to reduce maintenance requirement.

44. **Advanced Lubrication Systems**
Utilize lower maintenance lubrication systems.

45. **Advanced Micro Mechanical Systems.**
Advanced micro mechanical will require less space, less maintenance, and be integratable with computer based monitoring and control systems.

46. **Ice Slurry for Cooling.**
Ice slurry has up to 5 times the cooling capacity of water, possibly permitting smaller, more reliable cooling sytems.

47. **Advanced Machinery Control**
Develop advanced machinery control systems, with enhanced logic reducing need for intervention by personnel to maintain target state.

48. **Advanced machinery monitoring & diagnosis.**
Advanced machinery health monitoring and diagnosis systems will provide more reliable diagnosis to focus condition-based maintenance.

49. **Virtual Presence – Maintenance**
Reduce personnel on board by having key maintenance personnel work from shore or alternate location, linked into ship through videoconference, groupware, etc.

50. **Automated Teller Machines.**
Deploy Automated Teller Machines to reduce personnel requirements for banking.

51. **Improved Food Services.**
Deploy advanced technologies for food storage and preparation. Generate improved galley layouts to increase efficiency of preparation and serving tasks.

52. **Virtual Presence - Medicine.**
Reduce medical personnel on board through telepresence using video conferencing or similar technologies, combined with data links for patient data.

53. **Improved Husbandry**
Conduct studies and complete modifications to reduce the requirement for cleaning the ship. A Smart Ship example includes the Large Waste Pulper that claimed a reduction of 116 person hours per week.

54. **Waste Treatment Systems**
Implement waste treatment systems to reduce personnel required for waste management. A Smart Ship example includes the Plastic Waste Processor which was claimed to have reduced 116 person hours per week.

55. **Cargo/Store Handling.**
Conduct analysis and design activities to increase the efficiency of cargo handling and storage, including the use of simulation as the basis for "what if" analysis to compare the impact of designs on performance and personnel requirements. Additional Smart Ship technologies in this technology area include deck cranes, use of package conveyors, and SNAP III bar code technology.

56. **Enhanced Mission Electronics.**
Research to reduce the maintenance requirements of shipboard electronic systems

57. **Automated Shipboard Food Service.**
Automate aspects of the food service system on board, such that preparation, service, and clean up personnel are reduced or eliminated.

58. **Damage Control Support Systems.**
Implement damage control support systems onto existing vessels to reduce personnel requirement.

59. **Reduce Requirement for Damage Control.**
Develop vessels with reduced requirement for damage control due to higher survivability features.

60. **Integrated Platform Control.**
Develop integrated platform control systems, including the integration of semi-automated damage control systems.

61. **Automatic Fire Detection and Suppression Systems**
Implement automatic fire detection and suppressions systems, including computer based fire detection systems integrated with other ship systems.

62. **Unmanned Spaces.**
Deploy vessels with unmanned machinery spaces, to prevent loss of personnel in these areas when the compartment is damaged, as documented by the UK following the Falklands.

63. **Damage Control Automation.**
Develop automated damage control response systems.

64. **Unmanned Aerial Vehicles (UAVs) and robotics**
Fit ship with UAVs to reduce the requirement for helicopters or other aircraft, and use robotics to reduce ship personnel complement associated with air operations and maintenance.

65. **Contract Out Support Functions.**
Use contracts with commercial firms to contract out maintenance, support, and logistics functions – thereby reducing on-board personnel requirements in these areas.

66. **Eliminate Cumbersome Work Practices**
Some current practices require more crew than would streamlined practices. Effort in the US Navy's Capital Investment for Labor project is identifiying cumbersome work practices and solutions.

67. **USN Smart Ship Technologies or Commercial ship technologies**
Deploy integrated technologies onto ship that were evaluated as part of US Smart Ship including Fibre Optic Networks, Integrated Bridge Systems, Damage Control Systems, wireless communications, etc.

68. **US Navy Capital Investment for Labor solutions**
This programmed addresses labour intensive work practices, and shipboard tasks that could be made easier through changes in standard materials and equipment.

69. **Well-deck Overheads**
Installation of edge retentive, chemical resistant, heat resistant Sigma Edgeguard on entire well deck overheads on amphibious ships will eliminate all further maintenance for 10 years. This initiative affects 33 ships for a total savings of $24 million in life cycle maintenance and 30,000 Sailor man-days over a 10-year period.

70. **Preservation Teams**
Preservation teams will take over responsibility for organizational-level "chipping and painting" preservation and maintenance work to provide the quality assurance required for low maintenance finishes.

71. **Hydroblast Systems**
Procurement (lease, industry partnering or buy) of open/closed loop Ultra High-Pressure (UHP) waterjet (hydroblast) systems for removal of nonskid will result in significant savings in time and labor and a reduction of air and water contaminants.

72. **Re-allocate Functions and Tasks**
Re-allocate tasks on board ship such that tasks are re-distributed in a manner that reduces the need for some roles on ship.

73. **Wireless Internal Communications and Fibre Optic LAN.**
Implement wireless communication such that all on-duty personnel can locate other personnel, and allow person to maintain communication while away from a specific workstation. Implement Fibre Optic LAN to facilitate access to information systems throughout ship, eliminating need to be located at a specific workstation. Smart Ship examples in this area include the HYDRA and COMPASS technologies.

74. **Change Equipment Locations**
Re-locate or co-locate key equipment to generate a more efficient layout.

75. **Manning Requirements Analysis.**
Subject all sub-systems to manning requirements analysis.

76. **Design Process Including Human Element.**
Utilize a structured design process for new ship classes, including the human element at the core of that process (human centric, or user centric).

77. **User Friendly Man Machine Interfaces.**
Ensure all developed systems have properly design man machine interfaces, in order to reduce training requirement, allow transfer between positions, reduce skill fading and re-training, permit multi-tasking, etc.

78. **Advanced Design Techniques.**
Develop future ships using advanced design techniques, including the user of modelling and simulation such that personnel implications of designs can be constantly and iteratively evaluated, and accurate predications can be made.

79. **Advanced Computer Operations Support Systems.**
Approaches to monitoring the performance of platform-wide software using intelligent software agents should increase the reliability and performance of platform software

80. **Thin Server Technology.**
Specialized, network-based hardware platforms running a minimal operating system should provide increased reliability and ease of use.

81.

82. **Improved Crewing Predictions.**
Simulations of crew tasks that include the demands of secondary or emergency crew tasks

83. **DRDC Junior MARS Trainer.**
This simulation facility was developed for use in shore-based training of MARS officers. Because of its use of helmet-mounted displays, it could be implemented on-board.

84. **US TOM Training Recommendations**
The US TOM reports indicate a number of technologies that require significant investment (to be expanded in future version of this matrix).

85. **Develop New Manpower Personnel and Training Structure.**
Establish a new personnel structure, combining tasks. Change skill requirements in workforce through recruiting system to meet new job demands. Enhance training system.

86. **Advanced Training Technologies.**
Develop and implement enhanced training technologies (to be expanded in later version of this matrix).

87. **Flatten Rank Pyramid.**
Flatten the current rank pyramid, with less officers, reducing number and cost of personnel.

88. **Combine or Eliminate Existing Trades**
Combine or eliminate trades on existing vessels, with re-distribution of tasks as required. For example RN has combined stoker/electricians on its submarines whereas CA does not and has increased manning on the Victoria class as a result. Another example would be that CA has put a Steward and Coxn on the Victoria class whereas the RN concept did not have them.

89. **Assign Lower Ranks.**
Assign tasks to lower rank personnel (linked with flattening hierarchy as well), such as the reduction of 6 in Cs & POs from CPF to HFX and an increase of 12 in MS and below.

90. **Create New Multi Role Trades.**
For example the Type 23 use of support personnel for boarding parties.

91. **Train Alongside.**
Eliminate sea trainers - do all training alongside, thereby reducing officers spent on these vessels.

92. **Enhance Training Technology**
Spend more time training, use training technology to reduce training time required to acquire similar skill level, and ensure training is focused on the jobs assigned to individuals, all of which reduces duplication and ensures optimum performance from lower personnel numbers.

93. **Embedded Training.**
Embed training systems into onboard operational systems, reducing the need for added functions for training on board ship, and allowing personnel to maintain skill levels through impendent learning.

94. **Tailored Training.**
Focus training on specific task sets, such that individuals obtain training on skill required, allowing for wider mix of tasks by person (as opposed to broad trades).
Refs: Spindel et al., 2000;

95. **Improved Crewing Management**

96. **Manning Optimization Process.**
Complete a manning optimization process, using science and technology as demonstrated by US Navy program.

97. **UK Complementing Practice.**
Establish a complement estimating and monitoring practice similar to that in the Royal Navy.

98. **Manning Directorate**
Establish a manning directorate, and include in projects to constantly monitor and evaluate manning of ships.

99. **Organizational Commitment to Crewing Reduction.**
Study, plan, implement, and monitor a a top-down commitment to crewing reduction and associated changes in MPT systems.

100. **Optimized Detailing and Distribution**
Procedures and software for managing individual careers and

101. **Cost Management**
Identify and track operating costs, including personnel and incorporate in evaluation of personnel cost centres.

102. **Man for Missions.**
Establish ship complement for specific mission (e.g.: Send MCDVs for FISHPATS).

103. **Change Standards.**
Alter the standard for a class of ships (e.g.: decrease the cleanliness standard).

104. **Alter Sea-to-Shore Ratio.**
Contract maintenance, and/or hire an essential shore support group such that ship complement get a minimal shore rest and return to sea.

105. **Change Watch Systems.**
Consider watch systems that require fewer personnel (e.g.: 2 watch systems for engineering, 4-section watch systems). Note that Most Canadian ships sail on a 1: 2 watch rotation for all exercises and operations and may revert to a 1:4 rotation for transit passages only. Combat and CSE departments are normally mandated 1:3 or 1:4 and the supply department are predominantly day workers, although there is a duty supply tech. Departmental manning drives the rotation, as does the Ops and training requirements. Both Cbt and CSE are designed and manned to work 1:2 as the optimum readiness posture.

106. **Core and Flex Watch Systems**
Novel watch systems where a small core of personnel perform the basic ship tasks and a 'flex' team is available on an as-required basis.

107. **Disassociate Crews from Hulls.**
Operate ship more like an aircraft whereby the vessel is operated one a core crew, then is rotated for another crew and taken back out following any maintenance.

108. **Limit Functions.**
Re-consider operational capability required within Naval Task Group, for example, is it required that damage be fixed or simply survived?

109. **Limit Missions.**
Limit the type and range of missions assigned to a ship, reducing personnel required.

110. **Sequence Functions.**
Arrange shipboard tasks in sequence to reduce workload, and potentially staffing requirement. For example, sequence Operational Readiness checks

111. **Type 23 Procedure Experience.**

112. **Increase Productivity.**
Enhance tools, supplies, teamwork, and planning to enhance productivity.

113. **Advanced Practices for Getting the Best Out of the Crew.**
Develop new practices for getting the best out of lower personnel numbers and monitoring and maintaining performance, including procedures and instrumentation to determine amount of sleep, etc.

114. Human Systems Integration.
The technical process of integrating the five HSI domains: Human Factors Engineering, Manpower and Personnel, Training, System Safety, and Health Hazards with a Materiel System to ensure safe, effective operability and supportability.

115. **Modelling of Ship Tasks.**
Develop models of ship tasks and use them to Automate functions, Consolidate functions, and Simplify functions. In order to eliminate functions "For future ships, a detailed top-down functional analysis should be conducted, This will determine what information and resources are required for each function, how a team can be best structures to cope with needed information, how to complete required functions, and how functions change across the range of missions to be performed." (Spindel et al. 2000).

116. **Analysis of Tasks.**
Conduct task analysis to develop interface and workspace requirements and to allow more tasks to be done by one person.

117. **HSI Tools.**
Utilize Canadian tools in Directorate of Maritime Ship Support for Establishment estimation and associated shipboard space requirements.

118. **Techniques for Modelling Team Activities**
Continue to develop and utilize evolving techniques for modelling team activities to evaluate alternate team concepts, or alternate function distribution about existing teams.

Annex D: Findings from reviews of crewing reduction studies

From a report on Optimized Manning Case Studies completed for the US Navy. Prime Contract N61339-97-C-0066, Subcontract No. 0003

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1. It is important to find **leverage points**—changes with high payoffs. A combination of strategies is needed to identify leverage points. An understanding of current operations must be combined with a top-down analysis of function allocation that is not constrained by current operations.
2. **Iteration** is a constant theme of successful re-engineering efforts. New configurations of people and physical space, new procedures, and new technology cannot be expected to work perfectly the first time they are tested. Schedules and budgets must accommodate iterative design, testing, and modification.
3. A **clearly stated goal** is needed to establish the rationale behind new procedures and new technologies. If the primary goal is crew reduction, then all new technology must be evaluated against this goal.
4. **Training** is a key issue for crew reduction. In smaller crews, there is less opportunity for individuals to learn from more senior personnel on the job. The Navy must find ways to train skills currently learned from on-the-job apprenticeship and mentoring.
5. Reduced crew size has implications across **multiple modes of operation.** It may not be possible to provide optimal staffing in all situations and modes of operation. There is a tradeoff between costs and risks. Reduced crew size means that fewer people will be available to handle unusual situations. Analysis must be conducted for multiple possible scenarios and conditions, not just for the most likely scenarios.
6. Changes must take the larger **world context** into account. Many failures have been caused by designing equipment to operate in contexts that never materialized, or changed drastically after design. Crew reductions must be based on an accurate forecast of future missions.
7. Managing the **implementation of changes** is critical. Failures during implementation lead to resentment and skepticism. People at all levels of an organization must understand the changes that will affect them. Informal networks as well as formal organizational structures must be considered.
8. Across different types of organizations, the technologies that best support reductions in staffing levels fall into three categories:
   - Tools to build and maintain **situation awareness.**
   - Technology to support the use of **remote specialists.**

- **Central monitoring** systems that allow fewer, centralized humans to monitor a larger area.

These three technology areas have the most potential to support crew reduction.

9. Across different types of organizations, certain **measures can provide design criteria** for optimized manning:

- Ratio of decision makers to overall staff
- Percent time spent on overhead and information management tasks
- Concentration of expertise
- Message tracing
- Gridlocks on information flow
- Ratio of handoffs to transactions
- Ratio of information received to information sought
- Value of message outputs for cells in organization
- Degrees of separation between decision makers and raw data

Annex E: Statements of Work for Immediate Follow-on Activities

Two of the recommendations in the main report require immediate studies in order to support active ship acquisition projects. In order to facilitate the execution of this work draft Statements of Work have been prepared for potential use by the community.

These two activities fall within the scope of the Human Systems Integration project, being conducted by DRDC, through DSTHP 3, and therefore could be executed by this team. The two activities include:

1. Definition of Crew/Workload Reduction Technology Requirements for Future Ship Acquisition Documents

2. Creation of Statement of Work Elements to Incorporate a Human Systems Integration Complement Analysis Process in the ALSC Definition Phase

Definition of Crew/Workload Reduction Technology Requirements for Future Ship Acquisition Documents

Background and Scope

Recently a team from Defence Research and Development Canada (DRDC) was asked to lead a study of the technologies applicable to the reduction of crew workload and crew levels on current and future naval vessels. This research study identified 117 technologies, and then reviewed their applicability to Canadian ships with input from the naval community.

One of the recommendations of the research study was to further review the technologies and convert them into ship acquisition document language, as requirements and specifications. Further review of this recommendation suggested that it would be best to document these requirements and specifications in a DOORS database for two reasons; (1) the ALSC and CADRE projects are using DOORS to track their requirements and specifications, and (2) entry into DOORS would provide the ability to create traceable links from the statements back to the parent technology, and then back to the research projects that support that technology, thereby helping the projects to defend any requirements that they chose to use.

Objectives

The objectives of this activity are to:

1. Review the identified crew/workload reduction technologies and convert them into ship acquisition document language, as requirements and specifications,
2. Record the resulting requirements in a DOORS database, and
3. Provide this as a reference source to the ship acquisition community.

Work Tasks

The primary work tasks required to complete this activity include:

1. Review Results of Crew/Workload Reduction Technologies project reports.
2. Review the Requirements Management strategy for ALSC/CADRE, if there is one.
3. For each of the 117 technologies list in the Crew/Workload Reduction Technologies report, develop a set of requirements statements that could be used to integrate that technology into a ship acquisition. These requirements statements should be at two levels (1) performance requirement if possible, and (2) specific functional or technology specification. In combination, these statements will support future requirements for SORs and specifications for Specs.
4. Document the 117 technologies and the associated requirements in a linked DOORS database file, linking the requirements statement back to the parent technology, and the technology back to the references from where it was derived.
5. Deliver this requirement and specification statements in a brief report, and in the DOORS database.

Deliverables

The deliverables from this activity include:

1. A brief report summarizing the objectives, method, results and conclusions from the project.
2. A DOORS database file listing the resulting requirements and specifications, with links back to the parent technologies, and links from the technologies back to their parent references.

Creation of Statement of Work Elements to Incorporate a Human Systems Integration Complement Analysis Process in the ALSC Definition Phase

Background and Scope

Recently a team from Defence Research and Development Canada (DRDC) was asked to lead a study of the technologies applicable to the reduction of crew workload and crew levels on current and future naval vessels. This research study identified 117 technologies, and then reviewed their applicability to Canadian ships with input from the naval community.

A key conclusion made throughout the study was that the only way to achieve revolutionary changes to ship crew levels (more than a 10-20% reduction from current levels) was through the application of a Human Systems Integration process during the ship development process.

The Afloat Logistics Sealift Capability (ALSC) project is about to enter into its Definition Phase activities. During this phase it is intended that contractor teams will progress the scope and concept for the ship leading to preliminary designs and requirements/specifications around which the final contract will be awarded. This is the critical time when the Human Systems Integration process needs to be applied in order to successfully achieve crew level reductions. The technology review project therefore recommended that the ALSC project should include Statement of Work elements in their Definition Phase contracts to ensure that a Human Systems Integration process is followed, and that the ALSC project obtain Human Systems Integration expertise to assist with management and oversight of these activities.

Objectives

The objectives of this activity are to:

1. Develop SOW items for the ALSC Definition Phase to ensure that contractor teams follow a Human Systems Integration process in determine concepts for the resulting ship concept and preliminary designs.
2. Provide Human Systems Integration oversight to the Definition phase in support of the ALSC project team.

Work Tasks

The work tasks under this activity include:

1. Review ALSC Definition Phase contracting strategy.
2. Review ALSC Definition Phase SOW draft to date, and Systems Engineering approach.
3. Develop SOW elements to ensure that the industry Definition Phase teams utilize a Human Systems Integration centred approach to Complementing Analysis when developing the concept and associated complement for the vessel.
4. Deliver SOW elements to ALSC PMO.
5. Provide SOW Edit and Evaluation Criteria development support to ALSC PMO.
6. Provide Human Systems Integration oversight and PM support to PMO throughout the ALSC definition phase. Cost dependent on scope and duration.

Deliverables

The deliverables from this activity will include:

1. Statement of Work items and associated evaluation criteria for inclusion in the ALSC Definition Phase Request for Proposal.
2. On-going Human Systems Integration technical support to the ALSC PMO.
3. Regular progress and evaluation reports of the Human Systems Integration progress of the Definition Phase teams.

List of symbols/abbreviations/acronyms/initialisms

ALSC	Afloat Logistic & Sealift Capability ship
AOR	Auxiliary Oiler Replenisher
CADRE	Command and Control and Area Air Defence Replacement Project
CG 1	Client Group 1 – the maritime sector of the DRDC research programme
CPF	Canadian Patrol Frigate
DC	Damage Control
DD-21	US Navy's Land Attack Destroyer for the 21st Century
DFAIT	Department of Foreign Affairs and International Trade
DGMDO	Director General Maritime Doctrine and Operations
DERA	Defence Evaluation and Research Agency (UK)
D Mar Strat	Directorate of Maritime Strategy
DMMCP	Directorate Maritime Major Capital Projects
DMMPP	Directorate Maritime Maintenance Policy and Planning
DMRS	Directorate of Maritime Requirements (Sea)
DMSS	Directorate of Maritime Ship Systems
DND	Department of National Defence
DNPP	Directorate of Naval Personnel Planning

DNPR	Directorate of Naval Personnel Requirements
DOORS	Dynamic Object-Oriented Requirements System
DREA	Defence Research Establishment Atlantic
DRDC	Defence Research and Development Canada
DSHRC	Directorate Strategic Human Resources Coordination
DSS	Decision Support System
DSTHP	Directorate of Science and Technology for Human Performance
DWAN	Defence Wide Area Network
FMG	Fleet Maintenance Group
FOCUS	Fleet Onboard Command Update System
HSI	Human Systems Integration
ICE	Integrated Command Environment (US)
MARLANT	Maritime Command - Altantic
MARPAC	Maritime Command - Pacific
MCDV	Maritime Coastal Defence Vessel
MORPS	Maritime Other Ranks Production Study
MRDOG	Maritime Research and Development Overview Group
MSEP	Maritime Systems Engineering Personnel
NAVSEA	(US) Naval Sea Systems Command

NCM	Non-Commissioned Member
NTIS	National Technical Information Service (USA)
PMO	Project Management Office
POC	Point of Contact
RAS	Replenishment At Sea
RnlN	Royal Netherlands Navy
SHINCOM	Shipboard Integrated Communications
SHINMACS	Shipboard Integrated Machinery Control System
SHINPADS	Shipboard Information Processing and Display System
SME	Subject Matter Expert
SOR	Statement of Requirements
SPAWAR	(US) Space and Naval Warfare Systems Command
TOM	Technologies for Optimized Manning
TOR	Terms of Reference
TRUMP	TRibal class Update and Modernization Project
TTCP HUM	The Technical Co-operation Programmed Human Factors Group
UAV	Unmanned (or Uninhabited) Air Vehicle
UNREP	Underway Replenishment

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This is the report of the first phase of a study initiated by Maritime Research and Development Overview Group of technologies for reducing crew on Canadian navy ships.

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14. ABSTRACT

(U) At the request of DGMDO, DRDC conducted a study of technologies for crewing reduction to catalogue known technologies, identify those that are applicable to the Canadian navy, and prepare proposals for a way ahead. Information received from contacts in Australia, The Netherlands, UK and USA, together with the results of two extensive literature reviews and world-wide-web searches was assembled into a matrix of technologies. The categories include whether the technology can be implemented at no cost to the ship, at minor cost, at major cost such as a refit, can be implemented in new ship builds, or will require further development to implement. Two workshops with the Working Group representatives and four focus groups with fleet operators were held to evaluate the applicability of these technologies to Canadian navy ships. Recommendations for the way ahead are that the Canadian navy should develop its own capability to evaluate workload and crewing reduction technologies and ship complements for existing and future ships. It is also recommended that DRDC should support that effort with short-term and longer-term activities.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) Human Systems Integration
Crewing reduction
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